REUSE POTENTIAL OF KNIT FABRIC DYEING INDUSTRY SLUDGE AS FERTILIZER

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REUSE POTENTIAL OF KNIT FABRIC DYEING INDUSTRY SLUDGE AS FERTILIZER

A thesis
by

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It is hereby declared that the thesis has been performed by the author under the supervision of Dr. Md. Mafizur Rahman, Professor of the Department of Civil Engineering, BUET. Neither this thesis nor any part of it has been submitted elsewhere for the award of any degree or diploma.

March,2019

Md. Ibrahim Hossain

DEDICATED
TO
MY BELOVED PARENTS &FAMILY MEMBERS

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
ASTM	American Standard of Testing and Materials
BDS	Bangladesh Standard
BOD	Biological Oxygen Demand
CETP	Central Effluent Treatment Plant
COD	Chemical Oxygen Demand
DAP	Diammonium Phosphate
DO	Dissolved Oxygen
DoE	Department of Environment
ECA'95	Environmental Conservation Act 1995
ECR'97	Environmental Conservation Rules 1997
EPA	Environmental Protection Agency
ETP	Effluent Treatment Plant
MoP	Murat of Potash
TCLP	Toxicity Characteristics Leaching Procedure
TDS	Total Dissolved Solid
TSP	Triple Super Phosphate
TKN	Total Kjeldahl Nitrogen
UNEP	United Nations Environment Program
UNIDO	United Nations Industrial Development Organizations
USEPA	United States Environmental Protection Agency
WWTP	Waste Water Treatment Plant

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ABSTRACT

Bangladesh is a land of agriculture where about 80% people are farmers. Due to infertility or poor fertility of land in many areas farmers suffer a lot. For the reason, there are a huge demand of fertilizers. The demand of using fertilizers is increasing day by day. It will be praiseworthy to find an alternative source of commercial fertilizer or soil amender.

There are more than 200 knit fabric dyeing industries in Bangladesh. These industries produce a huge amount of sludge that causes environmental pollution. In this study it was investigated to find out the reuse potential of knit fabric dyeing industry sludge as fertilizer.

In this study sludge samples were collected from two different type ETP distinctly Biological type ETP and Bio-chemical type ETP from two separate knit fabric dyeing industries located at Gazipur and Narayangonj in Bangladesh. The samples were collected twice from each type of ETP to conduct two sets analysis named SET1 and SET2. Samples were collected using grab sampling method. Only four samples (two from Biological type ETP and two from Biochemical type ETP) were studied. Sludge samples were dried at 105^0C for 24 hours in the laboratory. Various selected physical and chemical properties were investigated from the dried sludge sample after grinding. The investigation was carried out to find pH, water solubility, Nonmetals such as Carbon, Hydrogen, Nitrogen, Sulfur etc., Oxides such as Calcium oxide, Magnesium oxide etc., heavy metals such as Arsenic (As), Lead (Pb), Chromium (Cr), Nickel (Ni), Zinc(Zn), Cadmium (Cd), Copper (Cu), Mercury (Hg), Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Iron (Fe) and Zinc (Zn) from the analysis of sludge samples. Heavy metal analysis was done by using Atomic Absorption Spectrophotometer (AAS)(Shimadzu AA-6800). Aqua regia method was followed to prepare the solution. Then, solution was filtered through 0.45 μm pore size filter paper. The filtered sample was then analyzed using flame emission technique in Atomic Absorption Spectrophotometer (AAS) machine to determine the concentration of heavy metals - As, Pb, Cd, Cr, Ni, Cu, Hg, Na, K, Ca, Mg, Fe and Zn. Toxicity Characteristics Leaching Procedure (TCLP) test for the sludge sample was conducted to analyze the long term leaching potential of heavy metals using USEPA method 1311. Fertilizer characteristics and different type of fertilizers were studied. It was compared the fertilizer characteristics to sludge characteristics and growth of plantation in different sludge soil mixtures was observed.

It is observed that 14.67 - 24.94% C, 4.2 – 5.6% N, 1.68- 1.83% S, 0.45 – 0.59% P in the sludge of biological type ETP after anaerobic digestion and 3.24 – 23.50% C, 0.58 – 0.67% N, 0.34 – 0.54% S, 0.27 – 0.29% P in the sludge of biochemical type ETP after anaerobic digestion and little amount of other nutrients present.

The test results show that the heavy metals are As 0.138 – 0.82 mg/Kg, Cr 49.9 – 58.9 mg/Kg, Pb 29.0 – 36.8 mg/Kg, Hg 0.00 mg/Kg, Cd 0.00 – 0.50 mg/Kg, Ni 12.2 – 13.6 mg/Kg, Zn 695.1 – 886.6 mg/Kg, Cu 214.2 – 323.1 mg/Kg in the sludge of biological type ETP after anaerobic digestion and As 1.89 – 4.81 mg/Kg, Cr 11.60 – 16.2 mg/Kg, Pb 28.4

– 26.6 mg/Kg, Hg 0.00 mg/Kg, Cd 0.00 – 0.50 mg/Kg, Ni 4.6 – 5.2 mg/Kg, Zn 252.0 – 336.9 mg/Kg, Cu 40.0 – 61.7 mg/Kg in the sludge of biochemical type ETP after anaerobic digestion.

According to Fertilizer Recommendation Guide – 2012 by Bangladesh Agricultural Research Council the heavy metals present in both sludge of biological type ETP and biochemical type ETP are within the allowable limits.

In TCLP tests the concentration of heavy metals are As 0.0135 – 0.0317 ppm, Cr 0.022 – 2.99 ppm, Pb 0.129 – 0.187 ppm, Hg 0.00 ppm, Cd 0.00 ppm, Ni 0.020 – 0.028 ppm, Fe 37.43 – 128.27 ppm, Mn 0.0 – 1.82 ppm in the sludge of biological type ETP after anaerobic digestion and As 0.0065 – 0.0114 ppm, Cr 0.0 – 0.029 ppm, Pb 0.166 – 0.227 ppm, Hg 0.00 ppm, Cd 0.00 ppm, Ni 0.011 – 0.020 ppm, Fe 1.23 – 6.08 ppm, Mn 0.0 – 1.62 ppm in the sludge of biochemical type ETP after anaerobic digestion.

TCLP test results of two sets of analysis show that heavy metals (As, Cr, Pb, Hg, Cd, Ni, Fe, Mn) concentration are within the allowable limits according to Fertilizer Recommendation Guide – 2012 by Bangladesh Agricultural Research Council.

Two sets sludge sample test results show that knit fabric dyeing industry sludge can be used as fertilizer. It is necessary to fix the proper mixing ratio before using sludge as fertilizer. Mixing ratio depends on the soil characteristics. Sludge disposal volume will be reduced if it is used as fertilizer.

CHAPTER 1
INTRODUCTION

1.1 Introduction

In Bangladesh, the sludge of textile effluent treatment plant has been considered as a potential environmental threat due to its huge volume and chemical content.(Badrun Nessa et al., 2016) Most of the industries now have ETPs but the real scenario is many of them do not manage their solid sludge properly produced from the ETP. (www.textiletoday.com.bd/managing-textile-sludge-sustainability) There is a strong demand for environmentally safe reuse and effective disposal methods for sludge due to the increasing amount of sludge generated by the wastewater treatment plants. (Mary et al., 2014) Disposal of industrial sludge by environmentally acceptable means poses a very great challenge worldwide. (Parameswari M and Udayasoorian C, 2013) Preventing wastage of resources is an important priority for sustainability. Sludge from a wastewater treatment plant (WWTP) is such a resource that is often wasted. It is a source of nutrients and organic materials that can be used as a fertilizer.(Catherine N. Mulligan and Mehdi Sharifi-Nistanak, 2016) Land application of textile sludge can be a good solution, whereas it is cost-effective disposal method for treatment plants and also can provide a favorable fertilizer for agricultural lands. (T. D Maddumapatabandi et al., 2011) Land utilization of sludge could represent a step forward to more sustainable farming practices and municipal waste management. Achieving this purpose it is pivotal to know the heavy metal content in textile sludge as without investigating toxic substances it is not feasible to use sludge as a soil conditioner or fertilizer in agricultural land. (Mehari MuuzWeldemariam, 2014) The textile manufacturing sludge offered potential to offset N fertilizer requirement. (McGonigle et al., 2012) Broadly a fertilizer may be defined as any substance (chemical, organic and microbial) that is added to soil to supply nutrient elements required for normal plant growth. (Bangladesh Agricultural Research Council, “Fertilizer Recommendation Guide 2012”)

New cost effective methods for treating and recycling of sludge must be employed to prevent resources wastage and damaging the environment. High concentrations of different nutrients and organic materials enable use of sludge as a fertilizer in agriculture fields. Chemical fertilizers can easily leach through the soil where they are no longer available for plant usage. This problem can be solved by humus in the soil which is stable organic matter in the soil that can preserve nutrients for plants. Using sludge as a fertilizer can increase organic matter. In comparison to chemical fertilizers, using sludge as fertilizer can add various nutrients to the soil, and enhance soil fertility, while preserving nutrients in the root area.

1.2 Objectives Of This Study

Objectives

a) Finding the **nutrients** present in sludge in Effluent Treatment plant of some selected **KNIT DYEING** industries in Bangladesh.
b) **Finding Reuse potential of Sludge produced** in effluent treatment plant of KNIT DYEING industries **as fertilizer**.

1.3 Outline Of Methodology

I. Two different knit fabric dyeing industries were selected randomly. One industry with biological type ETP where as other one was with biochemical type ETP.
II. Sludge samples were collected from biological type ETP and biochemical type ETP to analyze the physical and chemical properties of sludge.
III. Carried the samples to the laboratory and prepared for analysis.
IV. Found out the nutrients present in sludge using standard test method.
V. Production process of knit fabric dyeing was studied to know the types of dyes, chemicals, auxiliaries used so that the chemicals or auxiliaries contributed in sludge formation could be registered to predict the nature of sludge.
VI. Treatment scheme of ETP were studied to be informed that whether any chemicals were used or not that were responsible for toxicity if any.
VII. Concentration of heavy metals (As, Cr, Ni, Cd, Pb, Zn, Cu, Fe, Na, K, Mg, Ca, Mn) were examined.
VIII. TCLP of heavy metals (As, Cr, Ni, Cd, Pb, Hg, Fe,Mn) were tested.
IX. Test analysis were performed before and 20 days after anaerobic digestion.
X. Different chemical and organic fertilizer properties (e.g. Single nutrient or "straight" fertilizers and multi nutrient fertilizers) were studied to compare with nutrients in sludge.
XI. Plantation in sludge and soil at different mixtures and growth of plant was observed.

1.4 Structure Of The Thesis

This study shows reuse potential of knit fabric dyeing industry sludge as fertilizer. The report contains five chapters and the chapter details are outlined as follows:

Chapter - 1: Introduction, in this chapter the objective, methodology and structure of the thesis are discussed.

Chapter – 2: Literature, a brief description, production process flow chart of knit fabric dyeing, name of dyes, chemicals, auxiliaries, characteristics of knit fabric dyeing industry wastewater, effect of pH, BOD and COD on sludge production, treatment methods for knit fabric dyeing industry wastewater, definition of sludge, characteristics of sludge, current disposal system of sludge, land filling, composting, incineration, current sludge management and disposal practices in Bangladesh, impacts of heavy metals on environment and health, leaching from industry sludge, soil fertility, essential nutrients for soil, functions of nutrients in plants , fertilizers and characteristics, types of fertilizers, guidelines to use fertilizers, maximum allowable limits of different toxic metals in chemical and organic fertilizers, maximum allowable limits of toxicity characteristics leaching procedure (TCLP) of sludge, soil conditioner/amendment, liming material, difference between fertilizer and soil conditioner/ soil amendment, nutrient composition (%) of commonly used chemical fertilizers, nutrient composition (%) of organic manure, previous studies on knit dyeing industry sludge as fertilizer, sampling plan, sample collection procedures, atomic absorption spectrophotometer (AAS) are presented in this chapter.

Chapter – 3: Describes methodology of the study.

Chapter – 4: Result and Discussions are published in this chapter.

Chapter – 5: includes Conclusion, References, Appendix A. Appendix B.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

Bangladesh is facing vital problems due to industrial pollution that jeopardize environment. The casual disposal of industrial effluent threatens human being and other lives on earth. A huge amount of water is used in the production process of knit fabric dyeing and discharged thereafter which is called effluent that may contain organic, inorganic and toxic substances. To prevent environmental pollution effluent treatment is must. Sludge produced in the effluent treatment plant must be disposed of with care. This chapter describes relevant literature in brief.

2.2 Process in Dyeing (Color) Factory

The process in dyeing (color) factory is described briefly in fig. 2.1.

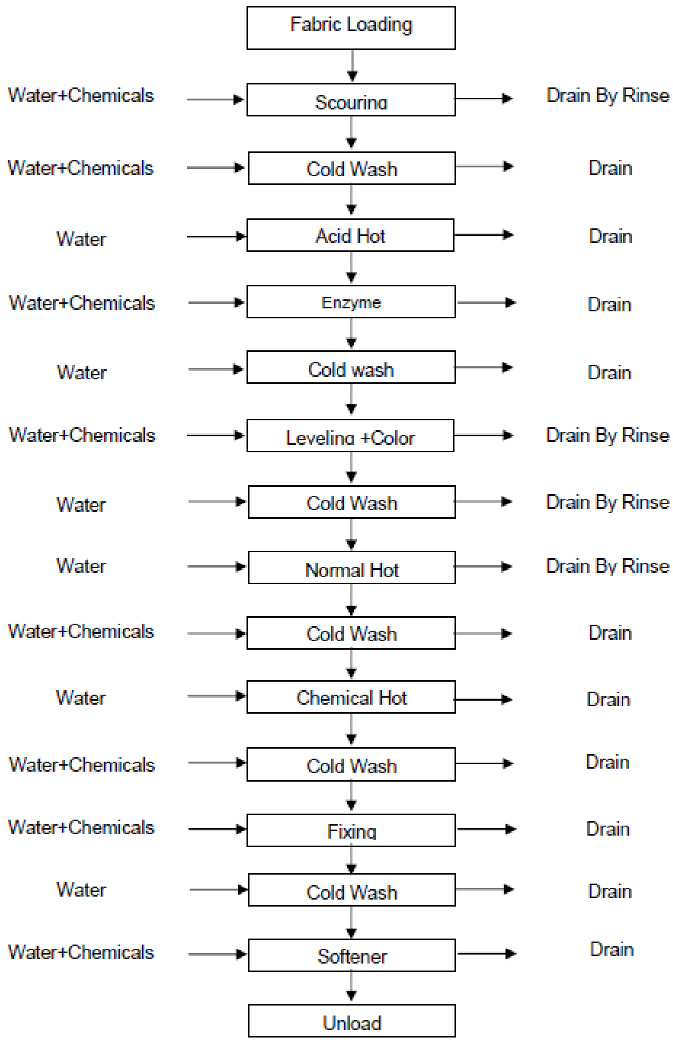

Fig. 2.1: Process Flow Diagram For Dyeing (Color)
(Source: Guide for Assessment of Effluent Treatment Plants, Department of Environment, June 2008, page A-24/67)

2.3 Dyes, Chemicals, Auxiliaries Used In Knit fabric Dyeing Industry

Dyes, Chemicals and auxiliaries used in knit fabric dyeing industry are listed in following Table 2.1.

Table 2.1 : Dyes, Chemicals and auxiliaries used in knit fabric dyeing industry

PROCESS	CHEMICALS/DYES/AUXILARIES	NATURE/IMPACT
Scouring & Bleaching	Detergent/ SOAP ($C_{17}H_{35}COONa$), Anti creasing agent (Polyacryl amide), Stabilizer (Sodium thiosulphate Na_2S_2O3), Sequestering agent (EDTA), Bleaching agent- H_2O_2, Ca(OCl)Cl	High alkalinity, High solids content with light to moderate BOD level
Hot Washing	Soaping agent (Polymer of poly acrylic acid ($C_3H_4O_2$)n	pH low/high, low BOD, Low COD
Neutralization	Acetic Acid (CH_3COOH)/ Formic Acid (HCOOH)	Neutral
Peroxide killer	Catalase Enzyme	Low pH
Enzyme Wash	Cellulaze enzyme	Low pH
Leveling	Leveling agent – PEG (Poly ethylene glycol CH_2OH – CH_2OH), Buffer Solution – Sodium Acetate (CH3COONa)	
Dyeing	Anti creaser, Sequestering agent, Glubar Salt ($Na_2SO_4.10H_2O$), Soda Ash Na_2CO_3, Reactive Dyes for Cotton, Disperse Dyes for Polyester, Acid Dyes for Nylon	Strongly colored, Fairly high BOD and COD
Soaping	Polymer of poly acrylic acid $(C_3H_4O_2)_n$	
Color Fixing	Color fixing agent – Poly amine ($C_{10}H_{26}N_4$)	
Softener	Softening agent – Animal fat / Vegetable fat	

(Source: Wikipedia wet processing engineering, fashion2apparel.blogspot.com /2017 /04/ textile-chemicals-auxilaries.html; textilelearner.blogspot.com/2013/04/major-chemicals-used-in-textile-wet.html)

2.4 Characteristics Of Knit Fabric Dyeing Industry Wastewater

Knit fabric dyeing process involves, in addition to extensive amounts of water and dyes, a number of inorganic and organic chemicals, detergents, soaps and finishing chemicals to aid in the dyeing process to impart the desired properties to dyed textile products. Residual chemicals often remain in the effluent from these processes. In addition, natural impurities such as waxes, proteins and pigment, and other impurities used in processing such as spinning oils, and oil stains present in cotton textiles, are removed during scouring and bleaching operations. This results in an effluent of poor quality, which is high in BOD and COD load. The following table lists typical values of various water quality parameters in untreated effluent from the processing of fabric using reactive, sulfur and vat dyes and compares these to the DoE effluent standards for discharge into an inland surface water body (e.g. river, lake, etc.). As demonstrated, the effluent from knit fabric dyeing industries is heavily polluted.
Table 2.2 shows the characteristics of untreated effluent from processing of knit fabric dyeing industry and DoE standards for discharge into an inland water surface body .

Table 2.2: Effluent Characteristics of Untreated Effluent from Processing of Fabric using Reactive, Sulfur and Vat Dyes and DOE Standards for Waste for Discharge into an Inland Surface Water Body.

Sl. No.	Parameters	Units	Typical Values	DOE Standards For Waste from Industrial Units or Project Waste - For Inland Surface Water Discharge
1	Appearance	-	Colloidal	-
2	pH	-	8 – 10	6-9
3	Color	-	Intensively colored	-
4	Heavy Metals	mg/l	10 – 15	Varies depending on type of metal
5	Suspended Solids (SS)	mg/l	200 – 300	150
6	Total Dissolved Solids (TDS)	mg/l	5000 – 6000	2100
7	Chemical Oxygen Demand (COD)	mg/l	1500 – 1750	200
8	Bio-chemical Oxygen Demand (BOD)	mg/l	500 – 600	50
9	Oil & Grease	mg/l	40 – 60	10
10	Surfactants	mg/l	10 – 40	-
11	Sulfide as S	mg/l	50 – 60	1

(Source: Guide for Assessment of Effluent Treatment Plants, Department of Environment, Ministry of Environment and Forest, Bangladesh, pp 35, June 2008)

Table 2.3 shows the effluent characteristics (pH, COD and BOD) from various wet textile processing operations. These can also be compared with the DoE standards listed in Table 2.2, showing the amount of contaminants present in the effluent from these processes.

Table 2.3: Effluent Characteristics of Various Wet Textile Processing Operations.

Sl. No.	Source of Effluent Generation	Parameters		
		pH	**COD (mg/l)**	**BOD (mg/l)**
A	**Process Effluent**			
1	Scouring	10.0 - 13.0	1200 - 3300	260 - 400
2	Bleaching	8.5 - 9.6	150 - 500	50 - 100
3	Dyeing	7.0 - 10.0	1000 - 3000	400 – 1200
B	**Wash Effluent**			
1	After bleaching	8.0 - 9.0	50 - 100	10 - 20
2	After acid rinsing	6.5 - 7.60	120 - 250	25 – 50
3	After dyeing (hot wash)	7.5 - 8.5	300 - 500	100 – 200
4	After dyeing (Acid & soap wash)	7.5 - 8.64	50 - 100	25 – 50
5	After dyeing (Final wash)	7.0 - 7.8	25 - 50	

(Source: Guide for Assessment of Effluent Treatment Plants, Department of Environment, Ministry of Environment and Forest, Bangladesh, pp 36, June 2008)

2.5 Effect of pH, COD and BOD on Sludge Production

Generally, the flock formation is completed by release of the natural poly electrolytes. These poly electrolytes consist of proteins and polysaccharides which are produced during the decomposition and bacterial death in endogenous phase. Also, these extracellular polymers play critical role in wastewater treatment, removal of contaminant and flock settling. In addition, these compounds have a key role in sludge treatment, sludge dewatering in biological digesters. Until recent years, these extracellular polymers were ignored and many researchers classified these compounds as volatiles and/or carbohydrates. Recently, isolation and extraction of these compounds was carried out by sonic processes or combination of sonic processes and cationic ion exchange resins. The findings indicate that proteins are the most important constituent of extracellular polymers which have been analyzed by pyrolises, HPLC, and mass spectrophotometeric procedures. The next findings indicate that polysaccharides are also present in the structure of these compounds, which was confirmed by gas chromatography and flame ionization. Since, main structure of these polymers consists of polysaccharides, proteins and lipids, and also this structure is severely affected by temperature; therefore, variation in temperature results in changed in polymer structure and bacterial cell wall. This in turn causes the variation in extracellular polymers and surface charge of bacteria, and in high temperature, extracellular polymers viscosity is decreased which results in reduction of bio-flocculation and settling. The studies on activated sludge systems show that most of biological systems and bacteria are activate in pH 4-9. Also, the pH in biological systems affects the enzymatic activities. Since, the released extracellular polymers have negative and neutralized charge in the most pH ranges and most of bacteria in pH 7 have isoelectric state, hence increasing the negative charge results in the increase of pH above the isoelectric point, which causes the increase of the active sites on the polymer surface and extracellular polymers. The increase of pH above the isoelectric point elongates the polymeric chain length and also induces the ability for bridging between bacterial cells, and ultimately improvement of biological flocculation occurs. Findings indicate that with increasing pH from 5.7 to 9.0, efficiency for COD reduction increased from 87% to 96% and amount of SS in effluent decreased from 87±6 mg/l to 49±4 mg/l. (Ghanizadeh et al., 2001)

The characterization of activated sludge and effluent is important aspect of facility design. The amount of oxygen required for chemical oxygen demand (COD) fulfillment is most important parameter along with biological oxygen demand (BOD). Their ratio plays key role in estimation of biodegradability of the effluent. (Dr. Sunil J et al., 2017)

The amount of sludge produced in waste water treatment plants, and that should be directed to sludge processing units, can be expressed in terms of mass (g of total solids per day, dry basis) and volume (m^3 of total solids per day, wet basis). In biological waste water treatment, part of the COD removed is converted into biomass, which will make up the biological sludge. (Macros Von Sperling et al., 2007)

Specific sludge production in wastewater treatment varies widely from 35 to 85 g dry solids per population equivalent per day (gTS PE-1 d-1).
The production of primary sludge is related to the amount of settleable solids in raw wastewater whose solids content is typically of 50-60 gTSS PE-1 d-1 or 110-170 gTSS/m3 of treated wastewater (Tchobanoglous et al., 2003).

Organic matter is oxidized by heterotrophic microorganisms to produce H_2O and CO_2 in the process known as catabolism. This process requires the availability of an electron acceptor – which may be oxygen or nitrate – and lead to the production of energy as ATP. This energy is then used by microorganisms to grow forming new cellular biomass and to guarantee maintenance functions (such as the renewal of cellular constituents, maintenance of osmotic pressure, nutrient transport, motility, etc.) in the process called anabolism.
Simultaneously biological decay of cellular biomass occurs, which creates two fractions:
- biodegradable particulate COD (XS);
- endogenous residue considered as inert particulate COD (XP), which accumulates in the system.

The XS fraction is subjected to hydrolysis process and is further oxidized to generate new cellular biomass (cryptic growth), while the endogenous residue (8-20%) remains and accumulates in the sludge.
A simplified scheme of these processes leading to sludge accumulation in a biological treatment of influent wastewater is indicated in the Figure.

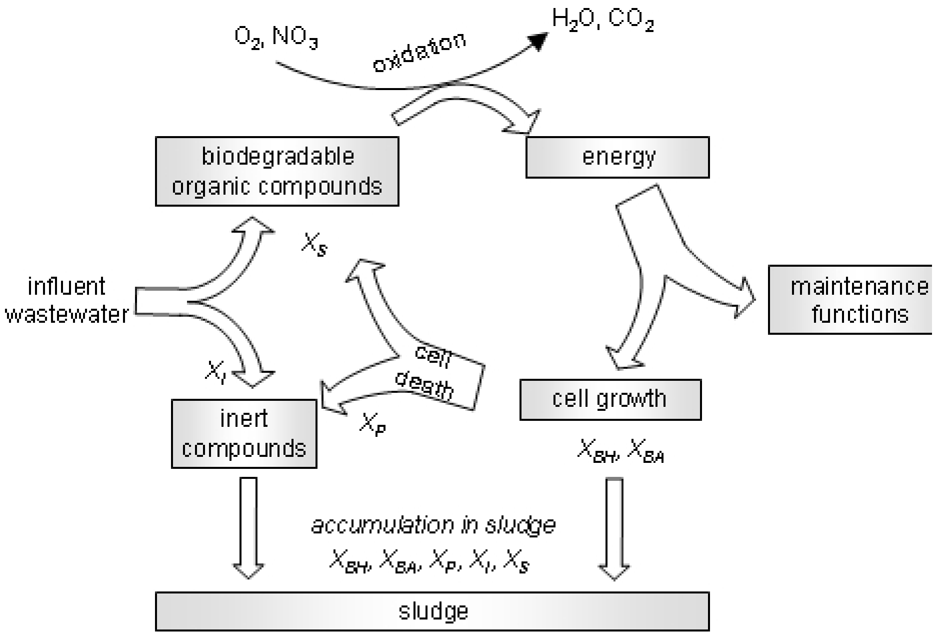

Fig.2.2: Simplified scheme of the processes leading to sludge production in the biological treatment of influent wastewater. (Paola et al., 2010)

The sludge is commonly quantified with reference to analyses of TS, VS, TSS, VSS, total COD or particulate COD. These measurements are different because they take into account the different constituents of sludge:

1) TS (Total Solids) = quantification of solids both in soluble and in particulate form, and both organic and inorganic;

2) VS (Volatile Solids) = quantification of organic solids, both in soluble and particulate form;

3) TSS (Total Suspended Solids) = quantification of particulate solids, excluding soluble solids both organic and inorganic;

4) VSS (Volatile Suspended Solids) = quantification of particulate organic solids, excluding soluble solids and inorganic solids;

5) Total COD = chemical oxygen demand including both particulate or soluble COD;

6) Soluble COD = chemical oxygen demand of soluble compounds.

7) Particulate COD = chemical oxygen demand of particulate compounds: estimated as the difference between total COD and soluble COD.

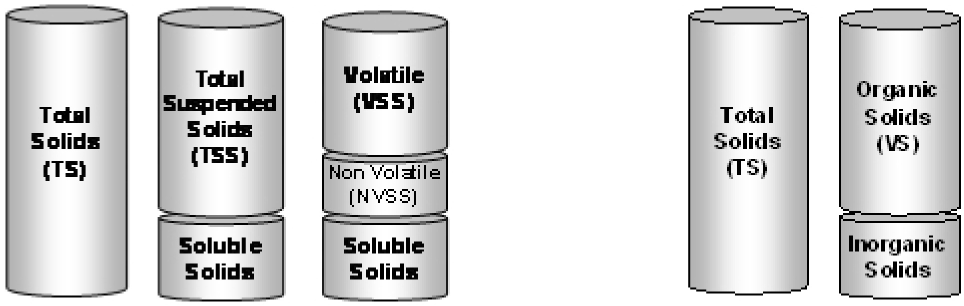

Fig. 2.3: Physical fractionation of total solids in sludge (Paola et al., 2010)

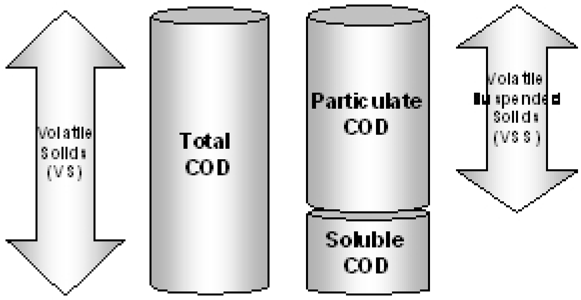

Fig. 2.4: Simplified physico-chemical fractionation of total COD in sludge. (Paola et al., 2010)

Total COD does not consider inorganic compounds, only organic ones and it is made up of a soluble fraction and a particulate one. A relationship exists with the VSS value, throughout the conversion factor, fcv, which typically is 1.42-1.48 mgCOD/mgVSS.

Particulate COD of sludge can be further subdivided in fractions (sludge fractionation as COD). The fractions are indicated with the symbol Xy, where X indicates the particulate form:

1) heterotrophic biomass (XBH): made up of heterotrophic bacteria involved in the biodegradation of organic matter;
2) autotrophic biomass (XBA): made up of nitrifying bacteria;
3) inert particulate COD (XI): derives from the inert particulate COD present in the influent wastewater and entering the plant. When it reaches the activated sludge stage, it is not affected by the biological treatment and accumulates in sludge;
4) endogenous residue (XP): residue of the decay process of bacterial biomass which accumulates in sludge;
5) biodegradable particulate COD (XS): the slowly biodegradable COD; in activated sludge with sufficiently long SRT this fraction is often small.

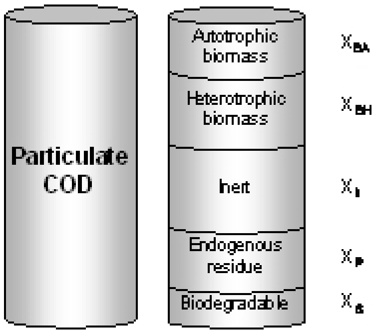

Fig. 2.5: Fractionation of particulate COD of sludge (Paola et al., 2010)

Particulate COD of sludge is made up of the terms involved in the following sum:

$$\text{Particulate COD} = XI + XP + XS + XBH + XBA$$

Omitting the two smaller fractions, XS and XBA, the composition of activated sludge can be approximated taking into account the following terms:

$$\text{Particulate COD} = XI + XP + XBH$$

In some cases, especially when the Sludge Retention Time (SRT) in a WWTP is long, the fractions XI and XP can be greater than the fraction XBH itself. (Paola et al., 2010)

2.6 Treatment Methods For Wastewater

Usually physical, Chemical or biological means are applied for wastewater treatment, and the treatment units are designed to carry out specific functions on the principles of either one or a combination of the means employed. Based on the means used, treatment methods have been broadly classified as unit operations and unit processes as described in the following paragraphs.

Unit operations:
The means of treatment in which the application of physical forces predominates are known as unit operations. Major treatment methods falling under this category are as follows:

- Screening
- Mixing
- Flocculation
- Sedimentation
- Floatation
- Elutriation
- Vacuum filtration
- Heat transfer and drying

Unit processes

The types of treatment in which the removal of contaminants is brought about by the addition of chemicals or the use of biological mass or microbial activities are known as unit processes. Based on the type of agent used, these are further classified as follows:

i. Chemical unit process
ii. Biological unit process

- Chemical unit process:

Reduction or removal is brought about by means of chemical reactions by adding chemicals. Major treatment methods falling under this category are as follows:

- Chemical neutralization: To control or adjust the system pH
- Chemical coagulation: To remove colloidal particles by chemical destabilization and flocculation.
- Chemical precipitation: To enhance the removal of suspended solids, phosphorus, heavy metals and BOD in specific system conditions.
- Chemical oxidation: To remove grease, ammonia, BOD, COD and for odour control in particular requirement.
- Chemical disinfection: To kill pathogens in influent and treated effluents.

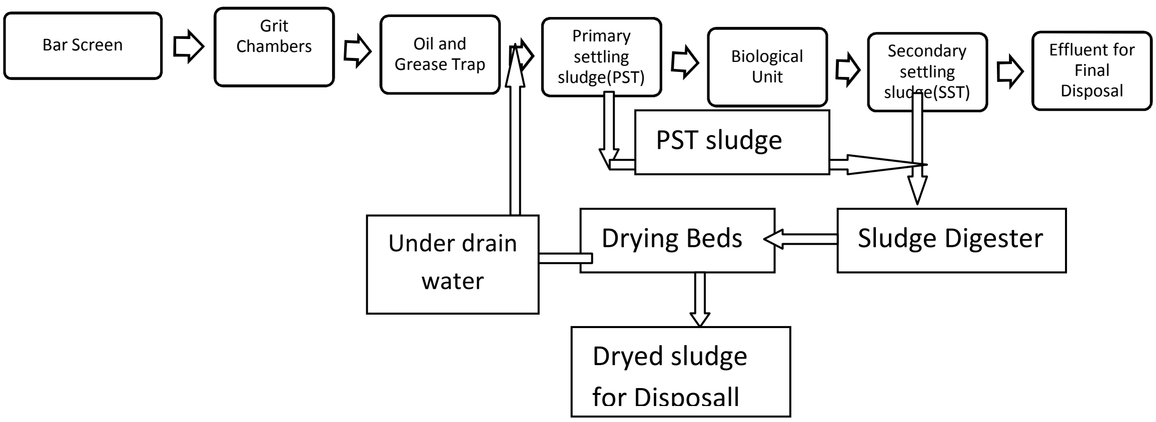

Fig. 2.6: ETP Process flow Diagram (Karia et al., 2013)

- Biological Unit Process:

Reduction or removal is brought about by microorganisms. Major treatment methods falling under this category are as follows:

- Suspended growth process: Activated Sludge Process, Aerated Lagoon, Oxidation Pond, Aerobic and Anaerobic Digesters etc.
- Attached growth process: Trickling Filter, Rotating Biological Contractors, Bio Towers, Up-flow Filters etc. (Karia et al., 2013)

2.7 Definition Of Sludge

Waste water treatment objectives are accomplished by concentrating impurities into solid form and then separating these solids from the bulk liquid. This concentration of solids, referred to as sludge.(Peavy et al., 1985) Most of the treatment processes normally employed in industrial water –pollution control yield a sludge from a solids-liquid separation processes (sedimentation, flotation etc.) or produce a sludge as a result of a chemical coagulation or a biological reaction (Eckenfelder, 1989).The solids and biosolids (formerly collectively called sludge) resulting from wastewater treatment operations and processes are usually in the form of a liquid or semisolid liquid, which typically contains from 0.25 to 12 percent solids by weight, depending on the operations and processes used. The term biosolids, as defined by the Water Environment Federation (WEF 1998), reflects the fact that wastewater solids are organic products that can be used beneficially after treatment with processes such as stabilization and composting. The term sludge is used only before beneficial use criteria have been achieved (Metcalf et al, 2003).

2.8 Characteristics Of Sludge

The characteristics of the residual streams generated in various treatment processes are primarily a function of treatment process, added chemicals, and quantity of raw water. An understanding of the quantity of sludge, solids content, and the nature of solids is essential to select and design the processing equipment properly (Syed R Qasim, 2000). The physical and chemical characteristics of sludges dictate the most technically and economically effective means of disposal. For thickening, the concentration ratio C_u/C_o(the concentration of the underflow divided by the concentration of the influent) is related to the mass loading [lb solids/(ft^2.d) or Kg/(m^2.d)], which indicates the feasibility of gravity thickening.

The dewater ability of a sludge by filtration is related to the specific resistance. While the specific resistance of a sludge can be reduced by the addition of coagulants, economic considerations may dictate alternative dewatering methods.
Ultimate disposal usually considers land disposal or incineration. When considering incineration, the heat value of the sludge and the concentration attainable by dewatering dictates the economics of the operation. Land disposal may use the sludge as a fertilizer or soil conditioner, as in the case of waste activated sludges or in a confined landfill for hazardous sludges. It is important that if a sludge is to be used for land disposal, heavy metals must be removed by pretreatment. (Eckenfelder et al, 1989)

The quantity and nature of the sludge generated relate to the character of the raw waste water and processing units employed. Primary settling produces an anaerobic sludge of raw organics that are being actively decomposed by bacteria. Therefore, these solids must be handled properly to prevent emission of obnoxious odors. In comparison with secondary biological waste, primary sludges thicken and dewater readily because of their fibrous and coarse nature, The following formula can be used to estimate the raw solids that are removed by plain sedimentation:

$$W_p = f.SS \quad (2.7 - 1)$$

Where W_p = raw primary sludge solids, pounds of dry weight per day (grams per day)

f = fraction of suspended solids removed in primary settling (f is 0.5 for domestic waste water)

SS = suspended solids in unsettled wastewater, pounds per day (grams per day) concentration of solids in unsettled waste water in mg/l*wastewater flow in mil gal/day * 8.34 lb/mil gal per mg/l (concentration of suspended solids in mg/l *flow in m^3/d)

Waste from aeration is flocculated microbial growths with entrained nonbiodegradable suspended and colloidal solids. It is relatively odor-free because of biological oxidation, but the finely divided and dispersed particles make it difficult to dewater. Excess activated sludge solids from aeration processes and humus from biological filtration can be estimated by Eq. 2.7 – 2, which relates solids production to BOD load. Although this formulation is responsible for domestic wastewater, calculated values may differ considerably from real sludge yields when treating municipal discharge that contains a substantial portion of industrial or food-processing waste.

$$Ws = K.BOD \quad (2.7 - 2)$$

Where W_s = biological sludge solids, pounds of dry weight per day (grams per day)

K = fraction of applied BOD that appears as excess biological solids , assuming about 30 mg/l of suspended solids in the plant effluent

BOD = BOD in applied wastewater after primary sedimentation, pounds/day (grams/day)

The total sludge solids production in a conventional treatment plant with primary sedimentation and secondary aeration is equal to the sum of the values calculated by above equations.

$$W_{ps} = W_p + W_s \qquad (2.7 - 3)$$

Where W_{ps} = total sludge solids from primary sedimentation and secondary biological aeration.

The sludge solids production for an activated-sludge system treating unsettled wastewater, for example, extended aeration without primary sedimentation, will be less than W_{ps} from Eq. 2.7 -3 but more than Ws from Eq. 2.7 – 2. The quantity of solids produced can be estimated based on the influent BOD of unsettled wastewater, disregarding the suspended solids, by increasing the value determined. Thus for aeration systems without primary clarifiers.

$$W_{as} = 2.0*K*BOD \quad (2.7-4)$$

Where W_{as} = biological sludge solids from activated sludge processing without primary sedimentation, pounds of dry weight per day (grams per day)

BOD = plant influent BOD without primary sedimentation, pounds per day (grams per day)

Design and operation of a sludge disposal system are based on volume of the wet sludge as well as the dry solids content. Once the dry weight of the solids has been determined, the volume of wet sludge can be calculated using Eq. 2.7 – 5 by knowing the percentage of solids, or water content. This formula assumes a specific gravity for the wet sludge of 1.0, which is sufficiently accurate for normal computations. For example, a slurry with 10 percent organics has a specific gravity of about 1.02.

$$V = W/ ((s/100)*8.34) = W / ((100-p)/100*8.34) \quad (2.7-5)$$

Where V = volume of wet sludge, gallons

W = weight of dry solids, pounds

S= solids content, percent

P= water content, percent

(Hammer et al, 2012.)

Typical data on the chemical composition of untreated sludge and digested biosolids are reported in Table 2.4.

Table 2.4: Typical chemical composition of untreated sludge and digested biosolids

Item	Untreated Primary sludge		Digested Primary sludge		Untreated Activated sludge
	Range	Typical	Range	Typical	Range
Total dry solids(TS),%	5 - 9	6	2 - 5	4	0.8 – 1.2
Volatile solids (% of TS)	60 - 80	65	30 - 60	40	59 - 88
Grease and fats (% of TS)					
Ether soluble	6 - 30	-	5 - 20	18	-
Ether extract	7 - 35	-	-	-	5 – 12
Protein (% of TS)	20 - 30	25	15 - 20	18	32 – 41
Nitrogen (N, % of TS)	1.5 - 4	2.5	1.6 - 3.0	3.0	2.4 – 5.0
Phosphorus (P_2O_5, % of TS)	0.8 – 2.8	1.6	1.5 – 4.0	2.5	2.8 – 11
Potash (K_2O, % of TS)	0 - 1	0.4	0 – 3.0	1.0	0.5 – 0.7

Cellulose (% of TS)	8 - 15	10	8 - 15	10	-
Iron (not as sulfide)	2.0 – 4.0	2.5	3.0 – 8.0	4.0	-
Silica (SiO_2, % of TS)	15 - 20	-	10 - 20	-	-
pH	5.0 – 8.0	6.0	6.5 – 7.5	7.0	6.5- 8.0
Alkalinity (mg/L as $CaCO_3$)	500-1500	600	2500-3500	3000	580-1100
Organic acids (mg/L as HAc)	200-2000	500	100-600	200	1100-1700
Energy content, KJ TS/Kg	23000-29000	25000	9000-14000	12000	19000-23000

(Source: Tchobanoglous et al, 2003)

Many of the chemical constituents, including nutrients, are important in considering the ultimate disposal of the processed solids and the liquid removed during processing. The measurement of pH, alkalinity, and organic acid content is important in process control of anaerobic digestion. The content of heavy metals, pesticides, and hydrocarbons has to be determined when incineration and land applications are completed.

Solids characteristics that affect their suitability for application to land and for beneficial use include organic content (usually measured as volatile solids), nutrients, pathogens, metals, and toxic organics. The fertilizer value of the sludge and solids, which should be evaluated where they are to be used as a soil conditioner, is based primarily on the container of nitrogen, phosphorus, and potassium (potash). Typical nutrient values of wastewater biosoilds as compared to commercial fertilizers are reported in Table 2.5.

Table 2.5 : Comparison of nutrient levels in commercial fertilizers and wastewater biosolids

Product	**Nutrients, %**		
	Nitrogen	**Phosphorus**	**Potassium**
Fertilizers for typical agricultural use	5	10	10
Typical values for stabilized wastewater biosolids (based on TS)	3.3	2.3	0.3

(Source: Tchobanoglous et al, 2003)

In most land application systems , biosolids provide sufficient nutrients for good plant growth. In some applications, the phosphorus and potassium content may be low and require augmentation.

Trace elements are those inorganic chemical elements that, in very small quantities, can be essential or detrimental to plants and animals. The term “heavy metals” is used to denote several of the trace elements present in sludge and biosolids. Concentrations of heavy metals may vary widely, as indicated in Table 2.6.

Table 2.6: Typical heavy metal content in waste water solids

Metal	Dry solids, mg/Kg	
	Range	Median
Arsenic	1.1 - 230	10
Cadmium	1 - 3410	10
Chromium	10 – 99,000	500
Cobalt	11,3 - 2490	30
Copper	84 – 17,000	800
Iron	1000 – 154,000	17,000
Lead	13 – 26,000	500
Manganese	32 - 9870	260
Mercury	0.6 - 56	6
Molybdenum	0.1 – 214	4
Nickel	2 – 5300	80
Selenium	1.7 – 17.2	5
Tin	2.6 - 329	14
Zinc	101 – 49,000	1700

(Source: Tchobanoglous et al, 2003)

For the application of biosolids to land, concentrations of heavy metals may limit the application rate and the useful life of the application site (Tchobanoglous et al, 2003).

2.9 Current Disposal System of Sludge

Several alternatives are available for ultimate disposal of effluent treatment plant residuals. Major disposal systems are i) landfill, ii) composting and iii) incineration.

2.9.1 Land filling

Sludge landfill can be defined as the planned burial of wastewater solids, including processed sludge, screenings, grit, and ash, at a designated site. The solids are placed into a prepared site or excavated trench and covered with a layer of soil. The soil cover must be deeper than the depth of plow zone (about 0.20 to 0.25 m). For the most part, land filling of screenings, grit, and ash is accomplished with methods similar to those used for sludge land filling (Davis et al, 1998).

Land application of biosolids is defined as the spreading of biosolidson or just below the soil surface. Biosolids may be applied to 1) agricultural land, 2) forest land, 3) disturbed land, and 4) dedicated land disposal sites. In all four cases, the land application is designed with the objective of providing further biosoilids treatment. Sunlight, soil microorganisms, and desiccation combine to destroy pathogens and many toxic organic substances. Trace metals are trapped in the soil matrix and nutrients are taken up by plants and converted to useful biomass (Metcalf et al, 2003).

Land disposal method may be broadly categorized into:

- open dumping – uncontrolled land disposal
- controlled dumping – some measures are taken to minimize the risk to public health and the environment
- sanitary land filling – a well-engineered method of waste disposal

Although it is not recommended, the method of disposal of solid waste developing countries is still open (and some controlled) dumping, mainly because of the rapid urbanization and the extreme shortage of capital in this sector. But social, political and cultural factors are also responsible for such disposal of waste. The overwhelming majority of landfills in Africa are open dumps and many of the landfills in Latin America are controlled dumps. There is a huge number (may be more than 60 percent) of uncontrolled landfills in Greece, Italy and Portugal. With the exception of a few countries like Japan and Singapore, all Asian countries mainly practice open dumping (with a few controlled dumps in India, Indonesia, Hongkong, Korea, Taiwan and Myanmar) for MSW. The open and controlled dump land disposal methods often do not satisfy hygienic, environmental and public health considerations. The cost of their remediation is very high, as are the costs of operation, maintenance, monitoring and cleaning up a sanitary landfill. These types of land disposals have been progressively phased out in most of the industrialized countries and have been succeeded by sanitary landfills.

Sanitary landfills are the engineered method of disposal of solid waste on land without creating nuisance, hazards to public health and safety or environment.

Present legislation, strategies and directives in solid waste management, particularly in North America and Western Europe, require a higher level of control to protect public health and the environment. In planning and implementing new landfills, particularly in industrialized countries, proper attention is paid to incorporating the requirements of state regulations and directives. For example, European Waste Landfill Directive (Solid Waste Disposal Facility Criteria 1991), requires landfill sites to satisfy a range of siting, design and operational requirements. The US Clean Air Acts have provisions for gaseous emissions from landfills, and the Federal Regulations for municipal solid waste landfills in the USA [in EPA Regulations on Criteria for Classification of Solid Waste Disposal Facilities and Practices (40 CFR 258)] demands sanitary landfills to meet the following requirements (USEPA, 1993):

- location criteria
- operation criteria
- design criteria
- groundwater monitoring and corrective action
- closure and post-closure care
- financial assurance

With these stringent technical requirements, the costs of landfills are increasing. The space available for landfill is also decreasing. Therefore, present policies in many developed countries are aimed at minimizing the amount of waste going to landfills. The European Commission (EC) directive (99/31/EC) requires its member states to have a strategy in place by July 2003 which will reduce the amount of biodegradable waste sent to landfill to 75 percent of total generated waste in 1995 by 2006, 50 percent by 2009 and 35 percent by 2009. But all these directives will not eliminate the need for future landfills as the essential final disposal option to receive residue from all other waste treatment options. Furthermore, in many situation a wide variety of waste is suitable for land filling. (Rahman et al., 2010).

2.9.2 Composting

Composting is an aerobic biodegradation scheme operated in a "solid state" format. Solid state means that the compost material behaves as a porous solid with a moisture content of 50 to 60 percent and through which air can be drawn to supply O_2 and to remove evaporated H_2O. Due to the high concentration of biodegradable organic material and the low moisture content of the compost mixture, the temperature rises to 60-70 ^{0}C during the time of peak biodegradation rates. In most cases, the air supply is determined by temperature considerations. If the temperature is too hot, more air circulation is needed to drive evaporative cooling. In parallel to control of air circulation, the moisture content must be controlled within the optimal range, 50-60 percent. Too much moisture prevents air circulation and slows microbial reactions. Too little moisture initially allows the temperature to rise above the optimal range; the excess temperature and concomitant desiccation of compost materials arrest biodegradation reactions. (Rittmann et al., 1982)

Composting is a cost effective and environmentally sound alternate for the stabilization of wastewater biosolids. Increasingly stringent air pollution regulations and biosolids disposal requirements coupled with the anticipated shortage of available landfills have accelerated the development of composting as a viable sludge-management option (Metcalf et al, 2003).

If the organic materials, excluding plastics, rubber, and leather are separated from municipal solid wastes and are subjected to bacterial decomposition, the end product remaining after dissimilatory and assimilatory bacterial activity is called compost, or humus. The entire process involving both the separation and bacterial conversion of the organic solid wastes is known as composting. Decomposition of the organic solid wastes may be accomplished either aerobically or anaerobically, depending on the availability of oxygen.

Most composting operations involve three basic steps: 1) preparation of the solid wastes, 2) decomposition of the solid wastes, and 3) product preparation and marketing.

Receiving, sorting, separation , size reduction, and moisture and nutrient addition are part of the preparation step (Peavy et al,, 1985).
The optimum moisture content for a compost mixture is 50 to 60 percent. Less than 40 percent limits the rate of decomposition, and over 60 percent is generally too wet for adequate ventilation. For efficient stabilization and pasteurization, the temperature in a compost pile should rise to at least 104^0F (40^0C) for 14 days , but not above 176^0F (80^0C).

Sludge cake for composting is usually raw organic solids dewatered using polymer as a conditioning chemical, although partially digested sludge may also be composted for additional stabilization (Hammer et al., 2012).

2.9.3 Incineration

After dewatering, the sludge cake must be disposed of . This can be accomplished by hauling the cake to a land disposal site or by incineration.

Incineration of sludge involves the total conversion of organic solids to oxidized end products, primarily carbon dioxide, water, and ash. The major advantages of incineration are 1) maximum volume reduction thereby lessening disposal requirements, 2) destruction of pathogens and toxic compounds, and 3) energy recovery potential (U.S.EPA, 1985a). Disadvantages include 1) high capital and operating cost, 2) highly skilled operating and maintenance staffs are required, 3) the residuals produced (air emissions and ash) may have adverse environmental effects, and 4) disposal of residuals, which may be classified as hazardous wastes, if they exceed prescribed maximum pollutant concentrations. Incineration is used most commonly by medium –to large sized plants with limited disposal options(Metcalf et al, 2003).

The variables to be considered in incineration are the moisture and volatile content of the sludge cake and the thermal value of sludge. The moisture content is of primary significance because it dictates whether the combustion process will be self-supporting or whether supplementary fuel will be required. The thermal values of sludges may vary from 5000 to 10000 Btu/lb (1.16×10^7 to 2.33×10^7 J/Kg)

Incineration involves drying and combustion. Various types of incineration units are available to accomplish these reactions in single or combined units. In the incineration process, the sludge temperature is raised to 212^0F (100^0C), at which point moisture is evaporated from the sludge. The water vapor and air temperature are increased to the ignition point. Some excess air is required for complete combustion of the sludge. Self-sustaining combustion is often possible with dewatered waste sludges once the burning of auxiliary fuel raises the incinerator temperature to the ignition point. The primary end products of combustion are carbon dioxide, sulfur dioxide, and ash.

Incineration can be accomplished in multiple-hearth furnaces in which the sludge passes vertically through a series of hearths. In the upper hearths, vaporization of moisture occurs and cooling of exhaust gases. In the intermediate hearths, the volatile gases and solids are burned. The total fixed carbon is burned in the lower hearths. Temperatures range from 1000^0F (538^0C) at the top hearth to 600^0F (316^0C) at the bottom. The exhaust gases pass through a scrubber to remove fly ash and other volatile products.

In the fluidized bed, sludge particles are fed into a bed of sand fluidized by up-ward moving air. A temperature of 1400 to 1500^0F (760 to 815^0C) is maintained in the bed, resulting in rapid drying and burning of the sludge. Ash is removed from the bed by the upward-flowing combustion gases. (Eckenfelder, 1989)

2.10 Current Sludge Management And Disposal Practices in Bangladesh

More than 200 Knit Dyeing (Composite) industries are present in Bangladesh. The average dry sludge production rate is about 21900 Tons per year (www.bkmea.com) . But there is no proper management and disposal practice of this large volume of sludge. Part of the sludge is used for land filling when most are accumulated in the premises of industry or outside area. There are no regulating body to monitor or to enforce the sludge management system.

Sludge management and disposal practices in the central effluent treatment plant of EPZ, Savar, Dhaka is depicted below:

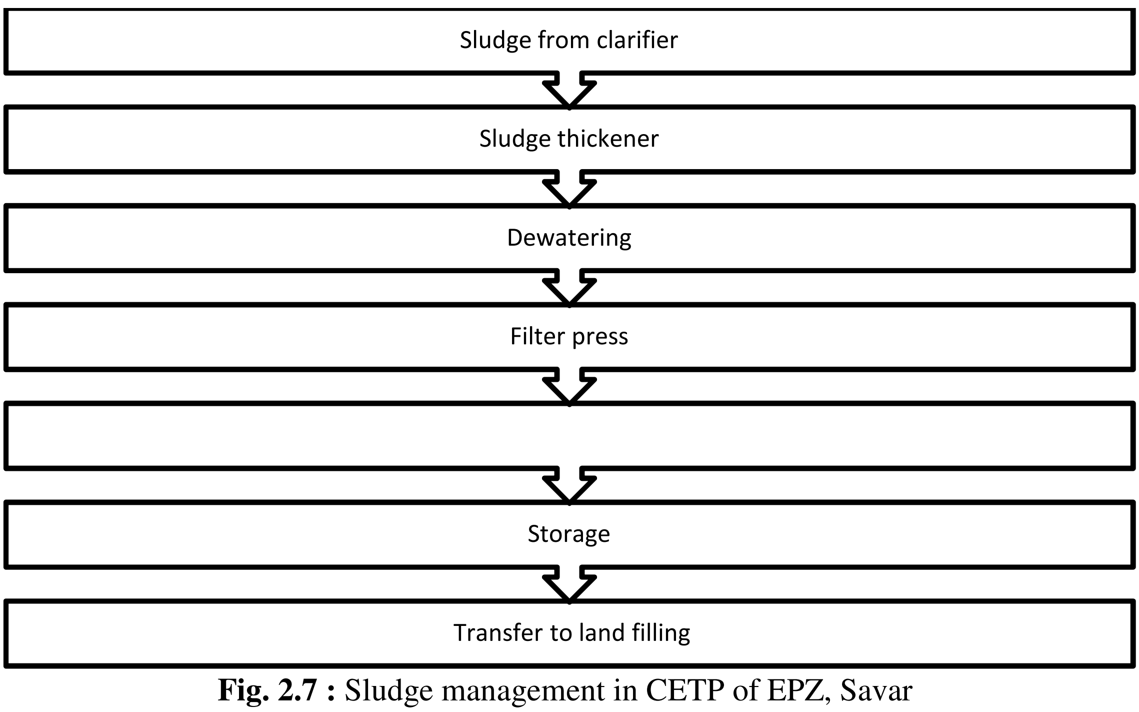

Fig. 2.7 : Sludge management in CETP of EPZ, Savar

Sludge from the clarifier is transferred to sludge thickening or holding tank (Fig. 2.8). After thickening sludge is passed to filter press machine (Fig. 2.9) through dewatering machine (Fig. 2.10). Sludge cake is produced in the filter press machine (Fig. 2.9) and stored(Fig. 2.11) for few months to transfer to land filling purpose.

Fig. 2.8 Sludge thickening tank

Fig. 2.9 Filter press machine

Fig.2.10 Sludge dewatering machine

Fig. 2.11 Sludge storage

2.11 Impacts Of Heavy Metals On Environment And Health

Heavy metals are naturally occurring elements that have a high atomic weight and a density at least 5 times greater than that of water. Their multiple industrial, domestic, agricultural, medical and technological applications have led to their wide distribution in the environment; raising concerns over their potential effects on human health and the environment. Their toxicity depends on several factors including the dose, route of exposure, and chemical species, as well as the age, gender, genetics, and nutritional status of exposed individuals. Because of their high degree of toxicity, arsenic, cadmium, chromium, lead, and mercury rank among the priority metals that are of

public health significance. These metallic elements are considered systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure. They are also classified as human carcinogens (known or probable) according to the U.S. Environmental Protection Agency, and the International Agency for Research on Cancer. This review provides an analysis of their environmental occurrence, potential for human exposure, and molecular mechanisms of toxicity, genotoxicity, and carcinogenicity.
The effects of heavy metals on environment and health are described briefly as below:

Effects Of Cadmium

Cadmium derives its toxicological properties from its chemical similarity to zinc an essential micronutrient for plants, animals and humans. Cadmium is biopersistent and,

once absorbed by an organism, remains resident for many years (over decades for humans) although it is eventually excreted.
In humans, long-term exposure is associated with renal dysfunction. High exposure can lead to obstructive lung disease and has been linked to lung cancer, although data concerning the latter are difficult to interpret due to compounding factors. Cadmium may also produce bone defects (Osteomalacia, osteoporosis) in humans and animals. In addition, the metal can be linked to increased blood pressure and effects on the myocardium in animals, although most human data do not support these findings.
The average daily intake for humans is estimated as 0.15µg from air and 1µg from water. Smoking a packet of 20 cigarettes can lead to the inhalation of around 2-4µg of cadmium, but levels may vary widely.

Effects Of Chromium

Low-level exposure of chromium can irritate the skin and cause ulceration. Long-term exposure can cause kidney and liver damage, and damage too circulatory and nerve tissue. Chromium often accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high levels of chromium.

Effects Of Copper

Copper is an essential substance to human life, but in high doses it can cause anemia, liver and kidney damage, and stomach and intestinal irritation. People with Wilson's disease are at greater risk for health effects from overexposure to copper.

Effects Of Lead

In humans exposure to lead can result in a wide range of biological effects depending on the level and duration of exposure. Various effects occur over a broad range of doses, with the developing fetus and infant being more sensitive than the adult. High levels of exposure may result in toxic biochemical effects in humans which in turn cause problems in the synthesis of haemoglobin, effects on the kidneys, gastrointestinal tract, joints and reproductive system, and acute or chronic damage to the nervous system.

Lead poisoning, which is so severe as to cause evident illness, is now very rare indeed. At intermediate concentrations, however, there is persuasive evidence that lead can have small, subtle, subclinical effects, particularly on neuropsychological developments in children. Some studies suggest that there may be a loss of up to 2 IQ points for a rise in blood lead levels from 10 to 20µg/dl in young children.

Effects Of Mercury

Mercury is a toxic substance which has no known function in human biochemistry or physiology and does not occur naturally in living organisms. Inorganic mercury poisoning is associated with tremors, gingivitis and/or minor psychological changes, together with spontaneous abortion and congenital malformation.

Monomethylmercury causes damage to the brain and the central nervous system, while fetal and postnatal exposure have given rise to abortion, congenital malformation and development changes in young children.

Effects Of Nickel

Small amounts of Nickel are needed by the human body to produce red blood cells, however, in excessive amounts, can become mildly toxic. Short-term overexposure to nickel is not known to cause any health problems, but long-term exposure can cause decreased body weight, heart and liver damage, and skin irritation. The EPA does not currently regulate nickel levels in drinking water. Nickel can accumulate in aquatic life, but its presence is not magnified along food chains.

Effects Of Selenium

Selenium is needed by humans and other animals in small amounts, but in larger amounts can cause damage to the nervous system, fatigue, and irritability. Selenium accumulates in living tissue, causing high selenium content in fish and other organisms, and causing greater health problems in human over a lifetime of overexposure. These health problems include hair and fingernail loss, damage to kidney and liver tissue, damage to circulatory tissue, and more severe damage to the nervous system.

Effects Of Arsenic

Inorganic arsenic is acutely toxic and intake of large quantities leads to gastrointestinal symptoms, severe disturbances of the cardiovascular and central nervous systems, and eventually death. In survivors, bone marrow depression, haemolysis, hepatomegaly, melanosis, polyneuropathy and encephalopathy may be observed. Ingestion of inorganic arsenic may induce peripheral vascular disease, which in its extreme form leads to gangrenous changes (black foot disease, only reported in Taiwan).

Populations exposed to arsenic via drinking water show excess risk of mortality from lung, bladder and kidney cancer, the risk increasing with increasing exposure. There is also an increased risk of skin cancer and other skin lesions, such as hyperkeratosis and pigmentation changes.

Studies on various populations exposed to arsenic by inhalation, such as smelter workers, pesticide manufacturers and miners in many different countries consistently demonstrate an excess lung cancer. Although all these groups are exposed to other chemicals in addition to arsenic, there is no other common factor that could explain the findings. The lung cancer risk increases with increasing arsenic exposure in all relevant studies, and confounding by smoking does not explain the findings.

The latest WHO evaluation concludes that arsenic exposure via drinking water is causally related to cancer in the lungs, kidney, bladder and skin, the last of which is preceded by directly observable precancerous lesions. Uncertainties in the estimation of past exposures are important when assessing the exposure–response relationships, but it would seem that drinking water arsenic concentrations of approximately 100 μg/l have led to cancer at these sites, and that precursors of skin cancer have been associated with levels of 50–100 μg/l.

The relationships between arsenic exposure and other health effects are less clear. There is relatively strong evidence for hypertension and cardiovascular disease, but the evidence is only suggestive for diabetes and reproductive effects and weak for cerebrovascular disease, long-term neurological effects, and cancer at sites other than lung, bladder, kidney and skin.

Effects Of Antimony

Antimony is a metal used in the compound antimony trioxide, a flame retardant. Exposure to high levels of antimony for short periods of time causes nausea, vomiting, and diarrhea. There is little information on the effects of long-term antimony exposure, but it is a suspected human carcinogen. Most antimony compounds do not bioaccumulation in aquatic life.

Effects of heavy metal toxicity on plants are summarized in Appendix -B

2.12 Leaching From Industry Sludge

Leaching is defined as the process by which a component of the waste is removed mechanically or chemically into solution from the solidified matrix by passage of a solvent such as water (Poon et al., 1985). Leaching is the process of release of contaminants from within the waste to the percolating water in soluble or suspended form (Peavy et al., 1985).

Leachate may be defined as liquid that has percolated through solid waste and has extracted dissolved or suspended materials from it. In most landfills, the liquid portion of the leachate is composed of the liquid produced from the decomposition of the wastes and liquid that has entered the land fill from external sources, such as surface drainage, rainfall, groundwater and water from underground springs.

As leachate percolates through the underlying strata, many of the chemical and biological constituents originally contained in it will be removed by the filtering and adsorption action of the material composting the strata. In general, the extent of this action depends on the characteristics of the soil, especiallythe clay content. Because of the potential risk involved in allowing leachate to percolate to the groundwater, best practice calls for its elimination or containment. Ultimately, it may be necessary to collect and treat the leachate (Peavyet al., 1985).

The assessment of the leachability of hazardous constituents like heavy metals in knit dyeing industry sludge subject to adverse situation is essential for regulatory purposes. There is well documented leaching test procedure TCLP (Toxicity Characteristics Leaching Procedure) can effectively minimize the condition as well as characterize the waste in terms of the leaching potential of the contaminants (Salma, 2012).

2.13 Soil Fertility

Soil fertility is the ability of the soil to supply nutrients required by plants in adequate quantities and correct proportions. Plants require at least 16 elements to complete their life cycle. They are: C, H, O, N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, Mo, B, Cl. Some of the lower plants in addition to the above elements require Co, V, Si. Among these C, H, O, N, P, K, Ca, Mg and S are required in large quantities and therefore called macronutrients and the others called micronutrients. The elements C, H, O are obtained mainly from air and water and the rest from the soil.

In a fertile soil, production is high at the start but diminish rapidly later due to exhaustion of the soil reserve of nutrients. In order to continue the high production of the pond, fertilizers containing the nutrients need to be applied frequently to the ponds. A good fraction of the fertilizers applied do not act directly on the organisms or water but often gets adsorbed on to the soil which releases the nutrients little at a time for a long period. As a result the fertilizers have prolonged action.

The amounts and kinds of fertilizers that need to be applied to the pond depend on the natural fertility of the soil.

Generalized ratings of the nutrient levels in agricultural soils are given in Table 2.7. The ratings may change slightly depending on the type of soil, ecology and the crop to be cultivated. However, they can be used as guides in interpreting soil test values. As there are no known ratings of soil nutrient values for aquaculture, the values given in Table 2.7. can be broadly used in determining the fertilizer needs of ponds.

Table 2.7: Ratings of soil nutrient values in agricultural soils (Loganathan, 1987)

Nutrients	very low	low	moderate	high	very high
N (total N,%)	<0.05	0.05–0.15	0.15–0.20	0.20–0.30	>0.30
P (available P, Bray and Kurtz No.1, ppm)	<3	3 – 10	10 – 20	20 – 30	> 30
K (exchangeable K, meg/100g)	<0.2	0.2–0.3	0.3–0.6	0.6–1.0	> 1.0
Ca(exchangeable Ca meg/100g)	<2	2 – 5	5 – 10	10 – 20	> 20
Mg (exchangeable Mg, meg/100g)	<0.3	0.3–1	1 – 3	3 – 8	> 8

(Source : Food and Agricultural Organization, FAO of the United Nations)

2.13.1 Essential nutrients for soil

Plant nutrients are of completely inorganic in nature. Plants require certain elements for their growth and development. But man and animals also require organic foodstuff (carbohydrates, proteins, fats and vitamins) in addition to inorganic nutrients. Plants contain more than 90 elements, however only 16 elements are known to be essential for their normal growth and development. Criteria for essentiality of a nutrient are: (i) a plant cannot complete its life cycle in the absence of the element, (ii) the function of the element cannot be carried out by another element, and (iii) the element is directly involved in plant metabolism. The essential nutrients are of two types: macronutrients and micronutrients. Macronutrients are required relatively in larger quantities and micronutrients are required relatively in smaller quantities. Macronutrient content of plants is usually above 0.1% (dry weight basis) and Micronutrient content is usually below 100 µg/g. Macronutrients are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium and sulphur. Micronutrients include iron, manganese, zinc, copper, boron, molybdenum and chlorine. In addition, several other elements are beneficial to some plants but are not considered essential for completion of life cycle of a plant. These beneficial elements are nickel, cobalt, sodium, silicon, selenium and vanadium. Except carbon, hydrogen and oxygen, all the 13 elements are taken up by plants from soils and they are called mineral nutrients. Plants usually obtain carbon, hydrogen and oxygen from air and water (Fertilizer Recommendation Guide 2012,Bangladesh Agricultural Research Council, chap. 2). Table 2.8 describes the source of plant nutrients in brief.

Table 2.8: Source of plant nutrients

Macronutrients		Micronutrients
Air and Water	Soil	Soil
Carbon (C) Hydrogen (H) Oxygen (O)	Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg) and Sulphur (S)	Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Boron (B), Molybdenum (Mo) and Chlorine (Cl)

(Source: Fertilizer Recommendation Guide – 2012 by Bangladesh Agricultural Research Council, pp 03)

2.13.2 Functions of nutrients in plants

Table 2.9: Functions of nutrients in plants

Nutrient	Functions
Nitrogen	Constituent of proteins and nucleic acids, integral part of chlorophyll, helps in vigorous vegetative growth with dark green color.
Phosphorus	Role in energy storage and transfer (ADP and ATP), constituent of nucleic acids, phytins and phospholipids, stimulates root growth, promotes fruit and seed formation, enhances nodulation in legumes.
Potassium	Involved in activation of enzymes related to starch synthesis, N metabolism and respiration, translocation of sugars from leaves to other parts, regulation of stomatal openings, produces stiff straw in cereals, imparts disease resistance to plants.
Calcium	Essential to cell membrane structure and permeability, role in cell elongation and division, helps in translocation of carbohydrates and nutrients.
Magnesium	Constituent of chlorophyll, involved in phosphate transfer from ATP, structural component of ribosome, required for maximal activity of phosphorylatic enzyme in carbohydrate metabolism.
Sulphur	Constituent of amino acids, biotin, Vit. B1, and coenzyme A, helps in nodulation of legumes, aids in the fats and oils formation, involved in chlorophyll synthesis
Iron	Component of cytochromes, ferrodoxins and leghaemoglobin, involved in the nitrogenase and nitrate reductase enzymatic reactions
Zinc	Synthesis of trytophane needed for the production of auxins, activation of dehydronease enzymes, involved in chlorophyll synthesis and cell membrane integrity.
Copper	Acts as an electron carrier in photosynthesis and respiration, constituent of cytochrome oxidase, synthesis of lignin that imparts strength of plants, helps in pollination and seed set.

(Source: Fertilizer Recommendation Guide – 2012 by Bangladesh Agricultural Research Council, pp 04)

2.14 Fertilizers And Characteristics

A fertilizer or fertilizer is any material of natural or synthetic origin (other than liming materials) that is applied to soils or to plant tissues (usually leaves) to supply one or more plant nutrients essential to the growth of plants. This also depends on its soil fertility as well as organic things such as humic acid, seaweed and worm castings.
Fertilizers enhance the growth of plants. This goal is met in two ways, the traditional one being additives that provide nutrients. The second mode by which some fertilizers act is to enhance the effectiveness of the soil by modifying its water retention and aeration. Fertilizers typically provide, in varying proportions:

- three main macronutrients:
  - Nitrogen (N): leaf growth;
  - Phosphorus (P): Development of roots, flowers, seeds, fruit;
  - Potassium (K): Strong stem growth, movement of water in plants, promotion of flowering and fruiting;
- three secondary macronutrients: calcium (Ca), magnesium (Mg), and sulphur (S);
- micronutrients: copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn), boron (B), and of occasional significance there are silicon (Si), cobalt (Co), and vanadium (V) plus rare mineral catalysts.

The nutrients required for healthy plant life are classified according to the elements, but the elements are not used as fertilizers. Instead compounds containing these elements are the basis of fertilizers. The macronutrients are consumed in larger quantities and are present in plant tissue in quantities from 0.15% to 6.0% on a dry matter (DM) (0% moisture) basis. Plants are made up of four main elements: hydrogen, oxygen, carbon, and nitrogen. Carbon, hydrogen and oxygen are widely available as water and carbon dioxide. Although nitrogen makes up most of the atmosphere, it is in a form that is unavailable to plants. Nitrogen is the most important fertilizer since nitrogen is present in proteins, DNA and other components (e.g., chlorophyll). To be nutritious to plants, nitrogen must be made available in a "fixed" form. Only some bacteria and their host plants (notably legumes) can fix atmospheric nitrogen (N_2) by converting it to ammonia. Phosphate is required for the production of DNA and ATP, the main energy carrier in cells, as well as certain lipids.

Micronutrients are consumed in smaller quantities and are present in plant tissue on the order of parts-per-million (ppm), ranging from 0.15 to 400 ppm DM, or less than 0.04% DM. These elements are often present at the active sites of enzymes that carry out the plant's metabolism. Because these elements enable catalysts (enzymes) their impact far exceeds their weight.

2.15 Types Of Fertilizer

Inorganic (Mineral) fertilizer: Fertilizer which contains nutrients in the form of inorganic salts obtained by extraction and/or by physical and /or chemical industrial processes, e.g. TSP, MoP, Gypsum etc.

Organic fertilizer: Carbonaceous materials mainly of plant and/or animal origin addedto the soil specifically for the nutrition of plants, e.g. cowdung, poultry manure, compost etc. It is known as manure.

Straight fertilizer: Fertilizer which contains only one primary nutrient (N, P or K), e.g. Urea, TSP and MoP.

Micronutrient fertilizer: Fertilizer which contains any micronutrient (Zn, B, Fe, Mn, Cu, Mo or Cl), which is required by plants relatively to smaller amount but essential for plant growth, e.g. Zinc sulphate, Boric acid, Copper sulphate etc.

Complete fertilizer: Fertilizer which contains all three primary nutrients (N, P and K).

Compound fertilizer: Fertilizer which contains at least two of the plant nutrients (N, P and K) obtained chemically or by blending or both, e.g. DAP.

Granular fertilizer: Solid material that is formed into a definite sized granule, e.g. USG, UMG.

Coated fertilizer: Granular fertilizer that is coated with a thin layer of different materials in order to improve the behavior and / or modify the characteristics of the fertilizer e.g. S coated urea. Both granular and coated fertilizers are known as slow release fertilizers.

Biofertilizer: Fertilizer that contains an active culture of beneficial microorganism which benefit the plants by providing nitrogen or phosphorus or rapid mineralization of organic material, e.g. Rhizobium, Azotobacter, Azospirillum etc.

Liquid fertilizer: Fertilizer that is in suspension or solution, e.g. liquefied ammonia.

Filter material: A substance added to fertilizer materials to provide bulk, prevent caking or serve some purpose other than providing essential plant nutrients

2.16 Guidelines To Use Fertilizers

Soil analysis, if properly done and rightly interpreted in relation to crop response, can be used as an effective tool for location specific and yield goal basis fertilizer recommendation. According to Bangladesh Agricultural Research Council (BARC) fertilizer recommendations are suggested for the high yield goal of a crop from low to optimum level of soil test values. Fertilizer recommendation is not suggested when soil test value goes beyond optimum level i.e. ranges between high and very high categories.

2.17 Maximum allowable limits of different toxic metals in chemical and organic fertilizers

Maximum allowable limits of different toxic metals in chemical and organic fertilizers are listed in the following Table 2.10.

Table 2.10: Maximum allowable limits of different toxic metals in chemical and organic fertilizers

Sl	Toxic metal	Chemical fertilizer (ppm)	Organic fertilizer (ppm)
1	Arsenic (As)	50	20
2	Cadmium (Cd)	10	5
3	Lead (Pb)	100	30
4	Mercury (Hg)	5	0.1
5	Chromium (Cr)	500	50
6	Nickel (Ni)	50	30
7	Zinc (Zn)	NA	0.1
8	Copper (Cu)	NA	0.05

(Source: Fertilizer Recommendation Guide – 2012 by Bangladesh Agricultural Research Council, pp 247)

NA : Not Applicable

2.18 Maximum Allowable Limits Of Toxicity Characteristics Leaching Procedure (TCLP) Of Sludge

Maximum allowable limits of toxicity characteristics leaching procedure (TCLP) of sludge as per EPA guide lines are listed in the following Table 2.12.

Table 2.11: Maximum allowable limits of toxicity characteristics leaching procedure (TCLP) of sludge as per EPA guideline

Sl	Toxic metal	Concentration (ppm)
1	Arsenic (As)	5.0
2	Cadmium (Cd)	1.0
3	Lead (Pb)	5.0
4	Mercury (Hg)	0.2
5	Chromium (Cr)	5.0
6	Zinc (Zn)	5.0
7	Nickel (Ni)	---
8	Copper (Cu)	---

(Source: 40 CFR, Part 261.31, USEPA 1992b)

2.19 Soil Conditioner/Amendment

A soil conditioner is a product which is added to soil to improve the soil's physical qualities, usually its fertility (ability to provide nutrition for plants) and sometimes its mechanics. In general usage, the term "soil conditioner" is often thought of as a subset of the category soil amendments (or soil improvement, soil condition), which more often is understood to include a wide range of fertilizers and non-organic materials.

Soil conditioners can be used to improve poor soils, or to rebuild soils which have been damaged by improper soil management. They can make poor soils more usable, and can be used to maintain soils in peak condition (Noble, March 2011).

A wide variety of materials have been described as soil conditioners due to their ability to improve soil quality. Some examples include biochar, bone meal, blood meal, coffee grounds, compost, compost tea, coir, manure, straw, peat, sphagnum moss, vermiculite, sulfur, lime, hydro absorbent polymers, and biosolids.

Many soil conditioners come in the form of certified organic products, for people concerned with maintaining organic crops or organic gardens. Soil conditioners of almost every description are readily available from online stores or local nurseries as well as garden supply stores.

Soil conditioners may be used to improve water retention in dry, coarse soils which are not holding water well. The addition of organic material for instance can greatly improve the water retention abilities of sandy soils and they can be added to adjust the pH of the soil to meet the needs of specific plants or to make highly acidic or alkaline soils more usable. The possibility of using other materials to assume the role of composts and clays in improving the soil was investigated on a scientific basis earlier in the 20th century, and the term soil conditioning was coined. The criteria by which such materials are judged most often remains their cost-effectiveness, their ability to increase soil moisture for longer periods, stimulate microbiological activity, increase nutrient levels and improve plant survival rates.

The first synthetic soil conditioners were introduced in the 1950s, when the chemical hydrolysed polyacrylonitrile was the most used. Because of their ability to absorb several hundred times their own weight in water, polyacrylamides and polymethacrylates (also known as hydroabsorbent polymers, superabsorbent polymers or hydrogels) were tested in agriculture, horticulture and landscaping beginning in the 1960s.

Interest disappeared when experiments proved them to be phytotoxic due to their high acrylamide monomer residue. Although manufacturing advances later brought the monomer concentration down below the toxic level, scientific literature shows few successes in utilizing these polymers for increasing plant quality or survival. The appearance of a new generation of potentially effective tools in the early 1980s, including hydro absorbent polymers and copolymers from the propenamide and propenamide-propenoate families, opened new perspectives.

Soil conditioners may be applied in a number of ways. Some are worked into the soil with a tiller before planting. Others are applied after planting, or periodically during the growing season. Soil testing should be performed prior to applying a soil conditioner to learn more about the composition and structure of the soil. This testing will determine which conditioners will be more appropriate for the available conditions (Soil Science Society of America. 2012).

2.20 Liming Material

An inorganic soil conditioner containing one or both of the elements calcium and magnesium, generally in the form of an oxide, hydroxide, or carbonate, principally intended to raise the soil pH, Dololime $[CaMg(CO_3)_2]$ is now commonly used in Bangladesh.

2.21 Difference Between Fertilizer and Soil Conditioner/ Soil Amendment

Fertilizers improve the supply of nutrients in the soil, directly affecting plant growth. Soil amendments improve a soil's physical condition (e.g. soil structure, water infiltration), indirectly affecting plant growth.

Soil amendments do not add concentrated nutrients to the soil but actually improve the texture. With a healthy, friable soil consistency, water and air pockets are readily available for plant roots as they spread prolifically in search of nutrients -- your plants develop deep and strong roots, along with tall and healthy stems and foliage. These amendments can be both organic or inorganic. Organic types, like worm castings, decay into the surrounding soil to add nutrients, although not as much as a typical fertilizer. Inorganic amendments, like gypsum, help water infiltration throughout the topsoil but do not contribute any nutritional benefits.

Fertilizers are concentrated nutrient amounts that we physically add to the soil for a direct plant growth influence. This nutrient addition, however, does not help soil's texture. For example, a compacted and poorly managed garden will not automatically grow if fertilizer is spread across the topsoil. In fact, the concentrated nutrients may simply run off since soil cannot absorb moisture well when compacted. Typically sold as synthetic mixtures, fertilizers are available in a number of different elemental mixtures as reflected by their ratios. A typical example is a fertilizer marked as 1-1-1. It has a balanced ratio of nitrogen, phosphorus and potassium available to plants after application.

2.22 Nutrient composition (%) of commonly used chemical fertilizers

Commonly used chemical fertilizers are Urea, Ammonium Sulphate, Triple super phosphate, Monoammonium phosphate, Diammonium phosphate, etc. Nutrient composition (%) of commonly used chemical fertilizers areshown in the following table. Table 2.12 describes the nutrient composition of commonly used chemical fertilizers.

Table 2.12: Nutrient composition (%) of commonly used chemical fertilizers

Source	Formula	N	P	K	S	Zn	Mn	Ca	Mg	B	Mo
Urea	$CO(NH_2)_2$	46	-	-	-	-	-	-			
Ammonium Sulphate	$(NH_4)_2SO_4$	21.1	-	-	23.5	-	-	-			
Triple super phosphate	$Ca(H_2PO_4)_2$	-	20	-	1.3	-	-	14			
Monoammonium phosphate	$NH_4H_2PO_4$	11	20	-	-	-	-	-			
Diammonium phosphate	$(NH_4)_2HPO4$	18	20	-	-	-	-	-			
Potassium chloride	KCl	-	-	50	-	-	-	-			

Potassium sulphate	K_2SO_4	-	-	42	17	-	-	-			
Gypsum	$CaSO_4.2H_2O$	-	-	-	18	-	-	20			
Magnesium Sulphate	$MgSO_4.H_2O$	-	-	-	12.5	-	-	-	9.5	-	-
Zinc Sulphate, Monohydrate (granular grade)	$ZnSO_4.H_2O$	-	-	-	18	36	-	-	-	-	-
Zinc Sulphate, Heptahydrate	$ZnSO_4.7H_2O$	-	-	-	11	23	-	-	-	-	-
Zinc oxide	ZnO	-	-	-	-	78	-	-	-	-	-
Boric acid	H_3BO_3	-	-	-	-	-	-	-	-	17	-
Solubor	$Na_2B_8O_{13}.4H_2O$	-	-	-	-	-	-	-	-	20	-
Manganese Sulphate	$MnSO_4.H_2O$	-	-	-	21	-	36	-	-	-	-
Ammonium Molybdate	$(NH_4)_6Mo_7O_{24}.2H_2O$	6.8	-	-	-	-	-	-	-	-	54
Sodium Molybdate	$Na_2MoO_4.2H_2O$	-	-	-	-	-	-	-	-	-	39

(Source: Fertilizer Recommendation Guide – 2012 by Bangladesh Agricultural Research Council, pp 247)

2.23 Nutrient composition (%) Of Organic Manure

Table 2.13 describes the nutrient composition of organic fertilizers that are used in plantation of many crops.

Table 2.13: Nutrient composition (%) of different organic manures/materials

Manure	N (%)	P (%)	K (%)
Cowdung (decomposed)	1.0±0.10	0.3±0.03	0.46±0.05
Farmyard manure	1.6±0.16	0.83±0.08	1.7±0.17
Poultry manure (decomposed)	1.25±0.13	0.7±0.07	0.95±0.1
Bio-slurry (Cowdung)	1.10±0.01	0.59±0.06	0.28±0.03
Bio-slurry (Poultry manure)	1.48±0.01	0.69±0.07	0.36±0.04
Compost (rural)	0.75±0.07	0.6±0.06	1.0±0.10
Compost (urban)	1.5±0.15	0.6±0.06	1.5±0.50
Compost (water hyacinth)	1.5±0.15	0.8±0.08	3.0±0.30
Mustard oilcake	5.0±0.50	1.8±0.18	1.2±0.12
Linseed oilcake	5.5±0.55	1.4±0.14	1.2±0.12
Sesame oilcake	6.2±0.62	2.0±0.20	1.2±0.12
Pressmud	1.85±0.18	0.13±0.02	0.54±0.05
Fishmeal	7±0.70	3.5±0.35	1.0±0.10

(Source: Fertilizer Recommendation Guide – 2012 by Bangladesh Agricultural Research Council, pp 248)

2.24 Previous Studies On Knit Dyeing Industry Sludge As Fertilizer

A major issue facing modern society is management of the waste that we produce. A growing emphasis has been placed on the three 'Rs': Reduce, Reuse, and Recycle. Composting provides a means of accomplishing all three of the Rs (Rahman et al., 2010).

There are no specific studies on knit dyeing industry sludge to be used as fertilizer but in broad spectrum there are many studies describes that Textile sludge or sewerage sludge or other solid wastes are being used as fertilizer after composting.
Anaerobic digestion is one of the oldest and still most commonly used processes for sludge stabilization. The first anaerobic digestion tanks were introduced over a hundred years ago in the United States. Concentrated organic and inorganic sludge matter is decomposed microbiologically in the absence of oxygen and converted to methane and inorganic end products. The main benefits from digestion are the stabilization of sewage sludge, volume reduction and biogas production.

2.25 Sampling Plan

Sampling is a primary investigation activity used to develop physical or chemical data that is representative for some volume of material for a given area or time period. Grab samples can only provide a "snapshot" of information. By their nature they are not representative but they do have an important role in data collection during an investigation.

The general idea is that a sampling plan should include as much information as necessary to ensure consistency from one sampling event to the next to eliminate sampling as the reason for data error.

The key elements of a sampling plan can be divided into four groups focusing on consistency, communication, documentation and data handling:

- 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, Target Reporting Level and key details regarding the facility.
- Proper sampling activity documentation includes proper sample labeling, chain-of-custody procedures and a log book of sampling activities.
- Data handling means that after all aspects of the sampling event are documented, the data is reviewed before the data gets submitted.

Sampling is the first, and perhaps the most critical area of the entire process of obtaining sludge quality information. A sample that is representative of the sludge being removed must be acquired in a manner that will not compromise its subsequent analysis. Sampling needs may vary depending upon site location, sample composition, logistics, time of collection, and analytes to be measured. It is also desirable that the final validated procedures are capable of being conducted at a reasonable cost. Sludge ranges from liquids containing less than 1 percent solids to pellets that are greater than 90 percent solids. Hence, a single approach to sampling is neither possible, nor appropriate.

Proper sampling is an integral part of monitoring the quality of sludge being removed for use or disposal. Information on sludge quality is used by the department in determining compliance with permit conditions, by generators in developing appropriate sludge management alternatives, and by management sites in determining whether the receipt of a customer sludge is compatible with their chosen sludge use or disposal option. In order to do this, a plan for representative sampling and analysis must be developed. It is required that all sampling procedures be documented in a sampling plan. Some elements that should be documented in a sampling plan include; the sampling points, volumes to be drawn, days and times of collection, required equipment, instructions for labeling samples and ensuring chain of custody, and a list of contact persons and telephone numbers in case unexpected difficulties arise during sampling. At a minimum, all domestic and industrial treatment works, and sludge management operations are required to maintain a sludge sampling plan on file which meets the following requirements:

1. Identify sludge sampling points at a location which assures homogeneity and best represents the physical and chemical quality of all sludge which is removed from the treatment works for use or disposal.
2. Sampling equipment to be utilized shall be identified and constructed of materials which will not contaminate or react with the sludge (for example, galvanized or zinc coated items may not be used); and
3. The sampling plan shall demonstrate adherence to quality assurance/quality control requirements and procedures for sampling and analysis, including decontamination procedures, consistent with the applicable analytical method.

In addition, site-specific factors must be considered when designing a sampling plan, and the sludge generation and handling process must be understood. For example, is the sludge generated in batches; is there a change in raw materials used in a manufacturing process; can waste composition vary as a function of process temperatures or pressures? Start-up, shut-down, slow-down and maintenance transients can result in the generation of a sludge that is not representative of the normal waste stream. If a sample was unknowingly collected at one of these intervals, incorrect conclusions could be drawn.

2.26 Sample Collection Procedures

Prior to implementing a sampling plan, it is often strategically important to walk through the sampling plan mentally, starting with the preparation of sampling equipment until the time when samples are received at the laboratory. This mental excursion should be in as much detail as can be imagined. By employing this technique, items not included on the equipment list may be discovered, as well as any major oversight that could cause the sampling effort to fail. During this review of the sampling plan, an attempt should be made to anticipate what could go wrong. A solution to anticipated problems should be found, and, if necessary, materials needed for solving these problems should be added to the equipment list. Proper collection procedures that must be addressed in a Sampling Plan include sample type, sample size, and sample equipment and containers.

Sample Type: By definition, samples of any media are either grab samples or composite samples. Grab samples are collected at one location and at one point in time. By contrast, composite samples consist of multiple grab samples taken over an area or time period.
For example, wastewater samples are usually individual grab subsamples collected from a discharge point at designated times over a 24-hour period then composited to represent the average concentration of that discharge.

Grab or composite samples may be appropriate depending on what the sample is being analyzed for and what the operator thinks is representative. A sample from a lagoon, drying bed, compost pile, or truck must consist of numerous samples collected from various locations in the lagoon, bed, pile, or truck that must be combined to make a representative sample. When analyzing for metals and nutrients, a minimum composite of five grab samples be taken over the period of sludge removal. On the other hand, when analyzing for microbiological parameters (for example, fecal coli form or salmonella), individual grab samples usually are required to be taken and analyzed. (Permits will often specify whether a grab or composite sample is to be taken; therefore, make sure that any permit that has been issued is consulted before designing a sampling plan.)

A grab sample is a specific quantity of sludge collected at a specific time and location. A single grab sample can represent sludge quality at the time and place it was collected. Extrapolating the analytical results of a single grab sample to represent an entire stockpile or continuous production is not valid. Grab sampling gains validity as historical data accumulates. One instantaneous data point may not convincingly establish sludge quality, but a database showing a consistent pattern may accurately depict sludge quality over time. For continuous processes, improving the comparability of the grab sampling data requires that equally sized samples are collected from the same location. The timing of the grab sample collection should be somewhat random to reflect temporal changes in the sludge. Samples to be submitted for microbial analyses are normally taken as grab samples, so that the time between sample collection and analysis can be documented.

A composite sample is many grab samples that have been collected and mixed together to form a single sample. Grab samples can be randomly collected from a location where sludge is stored, such as a roll-off container or stockpile. In a continuous process, grab samples are typically collected from the same location at a specific time interval over a given period of time. The size of the sample can be weighted to reflect time elapsed or flow. Generally, composite sampling is accomplished by collecting samples of equal size. In the case of continuous processes, the time interval between grab samples is typically kept constant. For example, a 24-hour composite could be obtained by collecting equal size samples every hour from a conveyor moving sludge between dewatering and the hauling vehicle. Data generated from the analyses of a composite sample are only representative of the average sludge quality produced during the time frame over which the sample was collected or of the "batch" that was sampled. As with grab samples, historical data provides the best representation of sludge quality.
In composite sampling, the grab samples that comprise the composite should be completely and thoroughly mixed either by the person performing the sampling or upon receipt in the certified laboratory. During the analysis process only a small portion of the overall sample is taken for analysis. If the composite sample is not thoroughly mixed, the subsample that is removed for analysis may only be representative of a single grab.

Sample size: Analytical protocols require minimum sample sizes to ensure analytical accuracy and precision. Laboratories should be consulted well in advance of any actual sample collection activities to ascertain the minimum sample size needed for each analytical method. The amount of sample collected will exceed the amount needed for analysis by a large margin. The sample generally must be reduced to a manageable size for the analyst to handle. Sample size reduction is more difficult for samples for microbial tests because care must be exercised to minimize opportunity for microbial contamination.

For freely flowing liquids, samples can be adequately mixed in the sample bottles by shaking the bottles. There must be room in the bottle for adequate mixing. Compositing of smaller samples is accomplished by pouring them into a larger bottle with adequate freeboard and mixing it by shaking or stirring it thoroughly with a sterile paddle. Pouring off a small part of the contents of a large container into a smaller bottle is a poor procedure, because the top layer of any slurry always contains fewer solids than lower layers. Sampling with a pipette with a wide bore is anacceptable alternative, provided the bore of the pipette is as wide as possible. The sample should be drawn into the pipette slowly and the tip moved through the sample to minimize selective collection of liquid over solid particles.

Sample size reduction for thick sludge is difficult, because shaking is not effective. Stirring with a mechanical mixer or a paddle is often inadequate. A satisfactory approach is to hand mix a composite of any subsamples, and then take a large number of small grabs from the large sample to form the smaller sample for the analyst.

For dry solid samples, the individual particles are frequently large and must be reduced in size to get a representative sample. If the particles are large and a number of subsamples must be combined into a large composite, it may be necessary to reduce the particle size before they are composited. This can be done in a sterile covered chopper, blender, or grinder. The individual subsamples are then combined and mixed by shaking, rotating, and tumbling. A smaller composite is then prepared by combining a number of grabs from all parts of the combined sample. Some other methods used to reduce size, such as "coning and quartering" (ASTM, 1992a) cannot be used for microbiological samples because it is difficult to avoid contaminating the sample when using these procedures.

Sample Equipment and Containers: The most important factors to consider when choosing containers for sludge samples are compatibility with the sludge, cost, resistance to breakage, and volume. Sampling equipment must be constructed of materials which will not contaminate or react with the sludge (for example, galvanized or zinc coated items cannot be used). Thus, it is important to be aware of the potential interactions between sampling equipment and/or container material with analytes of interest. This is true of all sampling equipment used. Containers must not distort, rupture, or leak as a result of chemical reactions with constituents of waste samples.
Thus, it is important to have an idea of the properties and composition of the sludge. The
containers must have adequate wall thickness to withstand handling during sample collection and transport to the laboratory. Containers with wide mouths are preferred to facilitate transfer of samples from samplers to containers.

Containers for collecting sludge samples are usually made of plastic or glass because these materials are relatively inert and easily cleaned. Glass containers are a good choice but they can be heavy and may be easily broken. Plastic containers have the advantage of lighter weight; however, they are not suitable for samples subject to analysis for organic compounds because of the potential for sample contamination from phthalate and other hydrocarbons within the plastic or adsorption of the target analyte to the sample container. Glass containers are the best choice for organic constituents, but covers or caps should be lined with Teflon. Sample containers should be filled with care so as to prevent any portion of the collected sample coming in contact with the sampler’s gloves, thus causing contamination. Samples should not be collected or stored in the presence of exhaust fumes.

If the samples are to be submitted for analysis of volatile compounds, the samples must be sealed in air-tight containers and filled according to the guidance in Test methods for Evaluating Solid Waste, Physical/Chemical Methods (EPA Publication SW-846), Method 5035. (New Jersy)

2.27 Atomic Absorption Spectrophotometer (AAS)

Atomic absorption spectroscopy (AAS) is a spectroanalytical procedure for the quantitative determination of chemical elements using the absorption of optical radiation (light) by free atoms in the gaseous state. Atomic absorption spectroscopy is based on absorption of light by free metallic ions.

In analytical chemistry the technique is used for determining the concentration of a particular element (the analyte) in a sample to be analyzed. AAS can be used to determine over 70 different elements in solution, or directly in solid samples via electro thermal vaporization , and is used in pharmacology, biophysics, archaeology and toxicology research.

Atomic emission spectroscopy was first used as an analytical technique, and the underlying principles were established in the second half of the 19th century by Robert Wilhelm Bunsen and Gustav Robert Kirchhoff, both professors at the University of Heidelberg, Germany.

The modern form of AAS was largely developed during the 1950s by a team of Australian chemists. They were led by Sir Alan Walsh at the Commonwealth Scientific and Industrial Research Organization (CSIRO), Division of Chemical Physics, in Melbourne, Australia.

In order to analyze a sample for its atomic constituents, it has to be atomized. The atomizers most commonly used nowadays are flames and electro thermal (graphite tube) atomizers. The atoms should then be irradiated by optical radiation, and the radiation source could be an element-specific line radiation source or a continuum radiation source. The radiation then passes through a monochromator in order to separate the element-specific radiation from any other radiation emitted by the radiation source, which is finally measured by a detector.

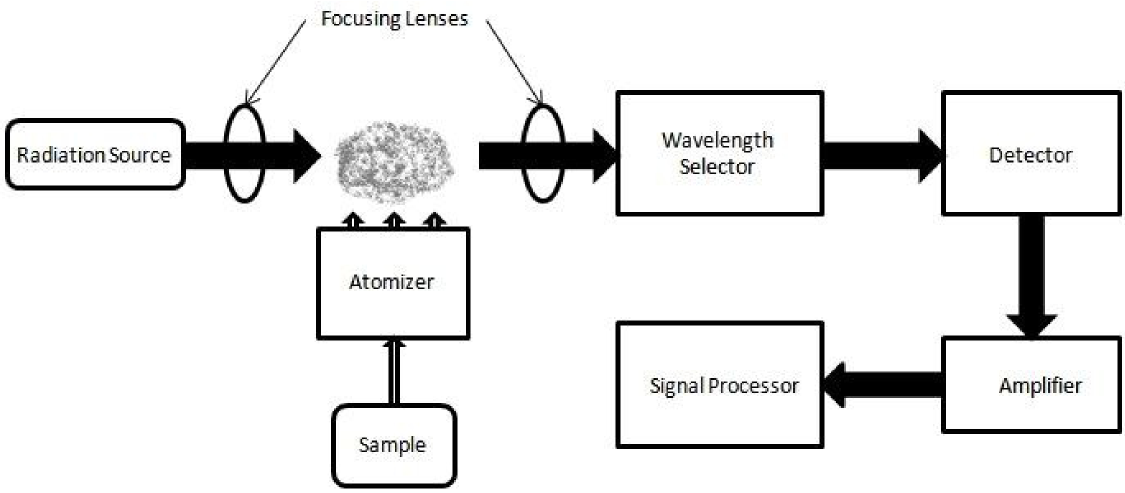

Fig. 2.12: Atomic absorption spectrometer block diagram

The atomizers most commonly used nowadays are (spectroscopic) flames and electro thermal (graphite tube) atomizers. Other atomizers, such as glow-discharge atomization, hydride atomization, or cold-vapor atomization might be used for special purposes.

The oldest and most commonly used atomizers in AAS are flames, principally the air-acetylene flame with a temperature of about 2300 °C and the nitrous oxide system (N_2O)-acetylene flame with a temperature of about 2700 °C. The latter flame, in addition, offers a more reducing environment, being ideally suited for analytes with high affinity to oxygen.

Liquid or dissolved samples are typically used with flame atomizers. The sample solution is aspirated by a pneumatic analytical nebulizer, transformed into an aerosol, which is introduced into a spray chamber, where it is mixed with the flame gases and conditioned in a way that only the finest aerosol droplets (< 10 µm) enter the flame. This conditioning process reduces interference, but only about 5% of the aerosolized solution reaches the flame because of it.

Fig.2.13 Atomic Absorption Spectrophotometer (Shimadzu AA 6800)

On top of the spray chamber is a burner head that produces a flame that is laterally long (usually 5–10 cm) and only a few mm deep. The radiation beam passes through this flame at its longest axis, and the flame gas flow-rates may be adjusted to produce the highest concentration of free atoms. The burner height may also be adjusted, so that the radiation beam passes through the zone of highest atom cloud density in the flame, resulting in the highest sensitivity.

The processes in a flame include the stages of desolvation (drying) in which the solvent is evaporated and the dry sample nano-particles remain, vaporization (transfer to the gaseous phase) in which the solid particles are converted into gaseous molecule, atomization in which the molecules are dissociated into free atoms, and ionization where (depending on the ionization potential of the analyte atoms and the energy available in a particular flame) atoms may be in part converted to gaseous ions.

Each of these stages includes the risk of interference in case the degree of phase transfer is different for the analyses in the calibration standard and in the sample. Ionization is generally undesirable, as it reduces the number of atoms that are available for measurement, i.e., the sensitivity.

In flame AAS a steady-state signal is generated during the time period when the sample is aspirated. This technique is typically used for determinations in the mg L^{-1} range, and may be extended down to a few µg L^{-1} for some elements.

Although the equipment appears completely different from other forms of absorption spectrometry, the law by which absorption of light is related to concentration is similar to that used for absorption of light related to concentration. The AAS is extremely sensitive technique and for common ions dilution prior to analysis is preferred.

The concentration range over which the law applies for Atomic adsorption Spectrometry (AAS) is usually 0-5 mg/L.

CHAPTER 3
METHODOLOGY

3.1 Introduction

The working procedure of the study is depicted in this chapter. The methodology of the study – industry selection, collection of Sludge samples, sludge preparation, analytical procedures to determine characteristics of sludge, finding the nutrients present in sludge, study of dyes, chemicals, auxiliaries used in knit fabric dyeing, heavy metal analysis, toxicity characteristics leaching procedure (TCLP) test, effect on environment, stabilization and composting of sludge, study of fertilizers properties, comparison of sludge characteristics with fertilizer characteristics ,observation of growth of plant in sludge and soil at different mixtures.
The methodology of this study is depicted in the flow chart as in Fig. 3.1.

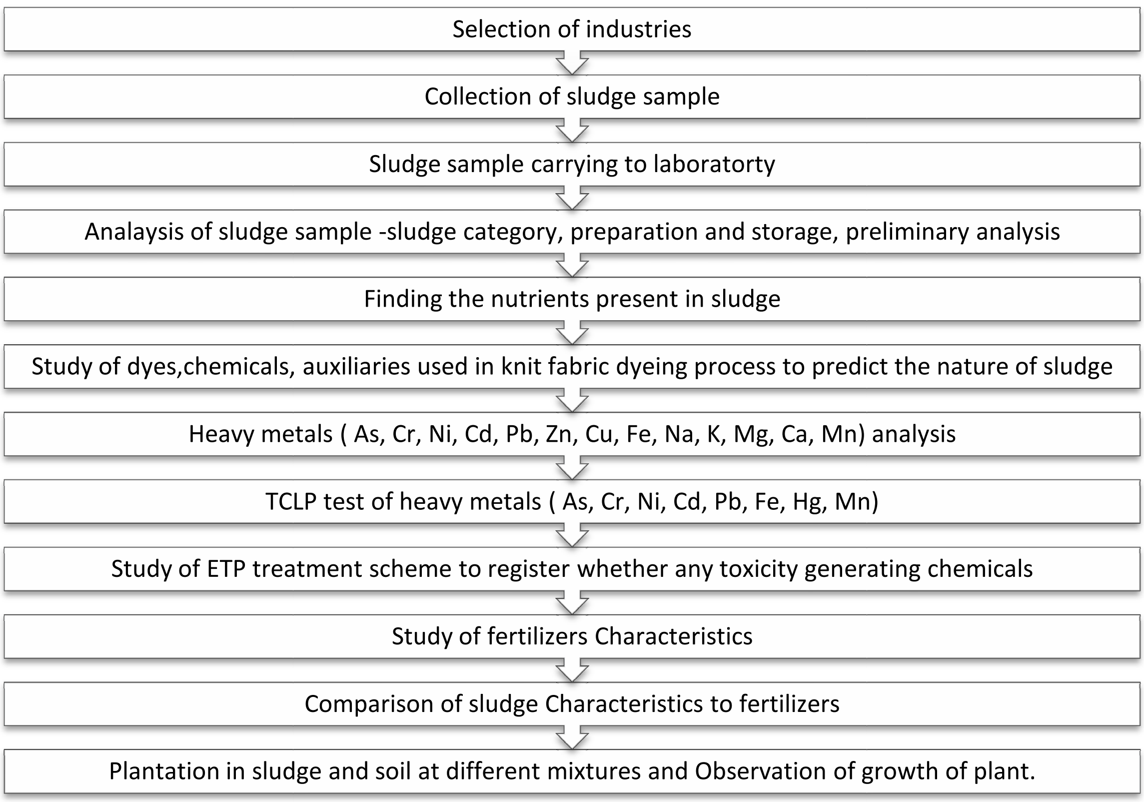

Fig. 3.1: Flow diagram of methodology of study

3.2 Selection Of Industries

There are more than 200 knit dyeing industries in Bangladesh (www.bkmea.com). These industries are discharging waste water through effluent treatment plant (ETP). Some industries are using bio-chemical type effluent treatment plant where as some are biological type ETP to treat the discharged waste water. For the analysis two industries been chosen randomly from two industrial zone namely Gazipur and Narayangonj, Bangladesh. One industry uses biochemical type ETP and other industry uses biological type ETP.

3.3 Collection Of Sludge Samples

Sludge samples were collected from The Delta Composite Knit Industries Ltd. possesses 100 m^3/h Biological Effluent Treatment plant located at South Jorun, Kashimpur, Gazipur (Figure 3.2) and Motaleb Monowara Composite (Pvt.) Ltd. possesses 40 m^3/h bio-chemical Effluent TreatmentPlant (ETP) located at Kutubail, Narayangonj (Figure 3.3) in the month of June 2016 and January 2017.

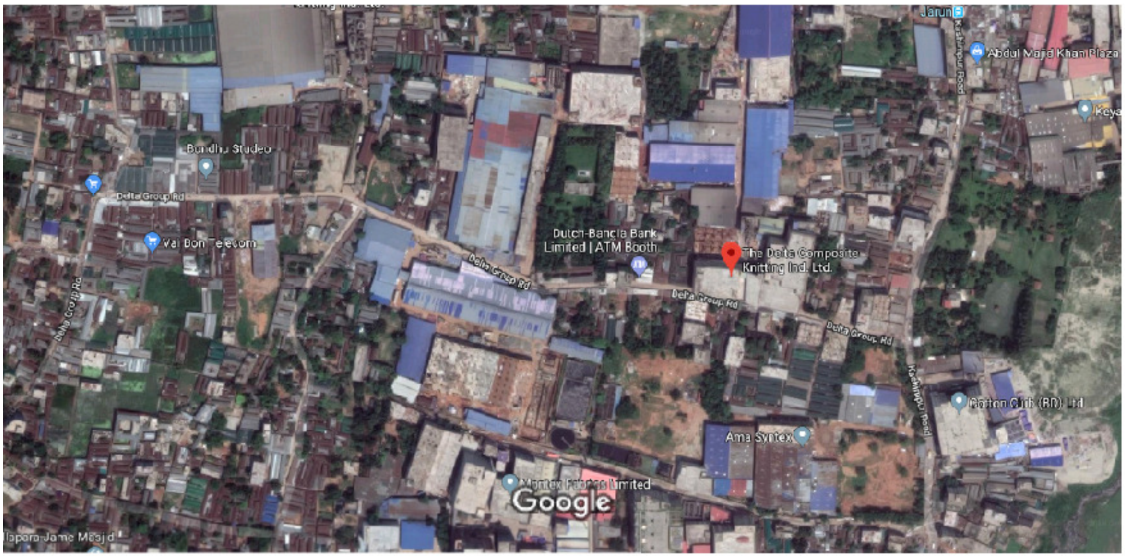

Fig. 3.2 Location Map of The Delta Composite Knitting Industry Ltd. (Source: Google)

These two factories are knit fabric dyeing industries. Sludge samples were collected for two times (June 2016 and January 2017) from each industry for two sets experiment.

Fig. 3.3 Location Map of MotalebMonowara Composite (Pvt.) Ltd. (Source: Google)

Both the factories are using treatment plant to treat the waste water discharged during knit dyeing process. The Delta Knit Composite Industries Ltd. uses only two chemicals in their ETP. Hydrochloric Acid to control pH and polymer (Poly-electrolyte) as flocculent. Motaleb Monowara Composite (Pvt.) Ltd. uses Hydrochloric Acid to control pH, Ferrous sulfate (FeSO4.18 H_2O), Lime ($Ca(OH)_2$) as coagulants and polymer (Poly-electrolyte) as flocculent.
Sludge samples were collected following grab sampling procedure.

Fig. 3.4 Raw sludge in plastic jar (3.64 liters) from The Delta Composite Knitting Ind. Ltd.

In the first factory, sludge generated from biological type effluent treatment plant is transferred to sludge thickener then to sludge drying beds for drying.
Raw sludge was collected from sludge drying bed shown in Figure3.4.

In the second factory, sludge generated from chemical type effluent treatment plant is transferred directly from clarifier to sludge drying bed.

Raw sludge was collected from sludge drying bed as shown in Figure 3.5.

Fig. 3.5 Raw sludge in plastic jar (10 liters) from Motaleb Monowara composite (Pvt).Ltd.

3.3.1 Sludge Carrying To Laboratory

After collection sludge sample was carried by using plastic jars, polythene bags and transported to laboratory.

3.4 Analysis Of Sludge Samples

Analysis of sludge was studied as described in the following article.

3.4.1 Sludge Category

Sludge samples were collected for two times from each type of ETP. For the first time experiment was done named SET 1 and second time named SET 2 to differentiate two different sets samples. The samples from biological type ETP were divided in two and designated as B1, B2 for SET1 and B3, B4 for SET 2. Similarly the samples from biochemical type ETP were divided in two and designated asC1, C2 for SET1 and C3, C4 for SET2. Therefore, each set consists of four samples. The four sludge samples were categorized as B1, B2, C1 and C2 for SET1 experiment and B3, B4, C3 and C4 for SET2 experiment. The legend is summarized as in the Table 3.1.

Table: 3.1 Sample Category

SET 1		SET2	
Samples		**Samples**	
B1	Biological type ETP sludge tested before digestion	**B3**	Biological type ETP sludge tested before digestion
B2	Biological type ETP sludge tested after 20 days anaerobic digestion	**B4**	Biological type ETP sludge tested after 20 days anaerobic digestion
C1	Biochemical type ETP sludge tested before digestion	**C3**	Biochemical type ETP sludge tested before digestion
C2	Biochemical type ETP sludge tested after 20 days anaerobic digestion	**C4**	Biochemical type ETP sludge tested after 20 days anaerobic digestion

3.4.2 Preparation of sludge Samples and storage

Immediately after the collection of sludge and categorize, samples B2, C2 and B4, C4 were kept for 20 days for anaerobic digestion. After that all the samples were dried at

105^0C for 24 hours to remove moisture. It was then grounded to make powder. Sludge Sample quantity was taken 5 grams for total extraction, 25 grams for TCLP, 20 grams for XRF system, 20 grams for Chemical Engineering Lab, BUET and 20 grams for Bangladesh Agricultural Research Institute (BARI) lab.

Then all the samples were kept in air tight plastic container for further analysis. The digested samples were preserved in disposable small plastic bottles band kept in a cool dry place before analysis. The leachate samples were also preserved in plastic bottles and the analysis was done within a short time after collection of sample for good results.

Fig. 3.6: Sludge samples grinding

Fig. 3.7: Grinding equipment

3.4.3 Preliminary analysis of sludge

Selected Physical and Chemical characteristics of sludge were tested . The characteristics were Specific gravity at 26 C, Solubility in Water, Color, pH, presence of Water Soluble Chloride, presence of nonmetal such as Carbon , Nitrogen, Phosphorus, Sulphur, Boron, presence of oxides such as CO_2**,** SiO2, Fe_2O_3, SO_3, Al_2O_3, ZnO, TiO_2, **,** RuO_2, Na_2O, CaO, MgO, P_2O_5, CuO, MnO, Cr_2O_3, NiO, heavy metals such as Sodium (Na), Potassium (K) , Calcium (Ca) ,Magnesium (Mg) ,Copper (Cu) ,Manganese (Mn) ,Iron (Fe) ,Arsenic (As) , Chromium (Cr) ,Lead (Pb) ,Mercury (Hg) ,Cadmium (Cd) ,Nickel (Ni) , Zinc (Zn).

The tests were performed in Environmental Engineering laboratory, BUET; Chemical Engineering laboratory, BUET; Glass & Ceramic Engineering department laboratory, BUET; and Bangladesh Agricultural Research Institute (BARI) laboratory, Gazipur. Tests were conducted following the standard test methods listed in Table 3.2.

Table: 3.2 Test method adopted for characterization of sludge

Parameter	Test method
Carbon (%),Specific gravity at 26^0 C, Solubility in Water, Color	ASTMD 5142-02
pH	BS:1377, Part:2; 1990
Water Soluble Chloride, (%)	BS:1377, Part:3; 1990
Total Extraction	ISO 11466.3
Detection of Heavy Metals: Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Copper (Cu), Manganese (Mn) ,Iron (Fe) , Chromium (Cr), Lead (Pb), Cadmium (Cd), Nickel (Ni), Zinc (Zn), ppm	SM 3111B
Mercury (Hg)	SM 3112B
Arsenic (As)	SM 3113B
TCLP test	EPA 1311
Detection of Heavy Metals: Chromium (Cr) ,Lead (Pb), Cadmium (Cd) , Nickel (Ni), Iron (Fe) , Manganese (Mn) ppm	SM 3111B
Mercury (Hg)	SM 3112B
Arsenic (As)	SM 3113B
CO_2,SiO2, Fe_2O_3,SO_3, Al_2O_3, ZnO, TiO_2, RuO_2, Na_2O, CaO, MgO, P_2O_5, CuO, MnO, Cr_2O_3, NiO, (%)	Fundamental Parameter Method in XRF
B	Azo-methyl H
P, S, N	Colorimetric method using Spectrophotometer

3.4.4 Finding nutrients present in sludge

Nutrients are the essential element of fertilizer. So, nutrients were investigated after preliminary analysis of sludge sample. Presence of nutrients expressed the potentiality of sludge as fertilizer. There are micro and macro nutrients in various concentration to compose different types fertilizers.

3.4.5 Study of dyes, chemicals, auxiliaries used in knit fabric dyeing process

Dyes, chemicals, auxiliaries used in the knit fabric dyeing process were studied briefly to predict the nature of sludge. As the dyes, chemicals and auxiliaries are composed of different element such as carbon, hydrogen, nitrogen etc. the sludge produced from the waste water treatment process also contained that said elements. So, it could be predicted about the sludge characteristics once we studied the dyes, chemicals, auxiliaries in knit fabric dying process.

3.4.6 Heavy metal analysis of sludge

Heavy metal analysis was done by using Atomic Absorption Spectrophotometer (AAS)(Shimadzu AA-6800) in the environmental engineering laboratory, BUET. Aqua regia method was followed to prepare the solution. In this method, 5 gm. of dried sludge sample was digested with acid (HNO3: HCl =1:3 volume ratio) for 24 hours. After adding 350-400ml distilled water, sample was boiled for 2.5 hours and prepared a 500ml solution. Then, solution was filtered through 0.45 μm pore size filter paper. The filtered sample was then analyzed using flame emission technique in Atomic Absorption Spectrophotometer (AAS) machine to determine the concentration of heavy metals - As, Pb, Cd, Cr, Ni, Cu, Hg, Na, K,Ca, Mg, Fe and Zn.

3.4.7 Toxicity characteristics leaching procedure(TCLP) test

Toxicity characteristic leaching procedure (TCLP) is a soil sample extraction method for chemical analysis employed as an analytical method to simulate leaching through a landfill. The testing methodology is used to determine if a waste is characteristically hazardous .The extract is analyzed for substances appropriate to the protocol. In the United States, the Resource Conservation and Recovery Act (RCRA) of 1976 led to establishment of federal standards for the disposal of solid waste and hazardous waste. RCRA requires that industrial wastes and other wastes must be characterized following testing protocols published by the Environmental Protection Agency (EPA). TCLP is one of these tests.

The toxicity Characteristics Leaching Procedure or TCLP is a standard USEPA test procedure (EPA method 1311). It is applicable for a wide range of wastes. The test is designed to model a theoretical scenario in which waste is placed in an unlined landfill with municipal solid waste and simulates the result of rainwater infiltration the landfill, reacting with the municipal solid waste, and then leaching through the waste being tested (EPA, 2002). Therefore, the result of the test implies long term leaching potential of the waste in the open environment. The test also aims at labeling wastes toxic/ non-toxic following regulatory limits on leaching set forth by EPA (USEPA, 1992b). This is test is an essential test in US to meet the land disposal restrictions.

TCLP comprises four fundamental procedures:

1) Initial evaluation of the sample
2) Determination of the appropriate extraction fluid
3) Rotary agitation of the solid phase of sample
4) Filtration of the extract and storage

The procedure is summarized below:

1) Initial evaluation of the sample

a. Determination of percent solids in the waste. If the percent solid exceeds 0.5% separation of solid and liquid phase is necessary for separate analysis. The liquid phase is filtered through a 0.6 to 0.8 µm glass fiber filter and considered the extract. The solid phase undergoes extraction.

b. Reduction of particle size (if necessary) to meet the maximum size limit set for TCLP. The waste particles for TCLP should not exceed 1cm.

c. Evaluation of the total metal concentration within the waste is performed to assess whether the waste is likely to leach significantly or whether the regulatory limits can be exceeded. The USEPA recommended formula (EPA,2002) for assessing maximum theoretical concentration in TCLP leachate from waste is expressed as:

$$((A \times B) + (C \times D))/(B+(20(L/Kg) \times D) = E$$

Where,

A = Concentration of the analyte in liquid portion of the sample (mg/L),
B = Volume of the liquid portion of the sample (L),
C = Concentration of the analyte in solid portion of the sample (mg/kg)
D = Weight of the solid portion of the sample (kg), and
E = Maximum theoretical concentration in leachate (mg/L).

2) Determination of the appropriate extraction fluid

The next step is for the non- volatile solids. There are two types of extraction fluid, namely, extraction fluid I and extraction fluid II, respectively. The extraction fluid I (EF-I) is specified to have a pH of 4.93±0.05 and the extraction fluid II (EF-II) is specified to have a pH 0f 2.88±0.5. The extraction fluid employed is a function of the alkalinity of the solid phase of the waste. For this purpose TCLP employs a completely different and lengthy technique for evaluation of pH . The steps are:

a) 5.0 gram of sample having particle size < 1mm (reduced) is taken and mixed thoroughly with 96.5 ml of de-ionized (DI) water and stirred vigorously for 5 minutes with a magnetic stirrer and allowed to settle. The pH is then measured and recorded.

b) If pH <5.0, extraction fluid–I (EF-I) is selected immediately and step 3 is followed.

c) If pH>5.0, 3.5 ml of 1(N) HCl is added, slurry is briefly mixed and covered with a watch glass. Then it is heated to 50 ^{o}C and kept at 50 ^{o}C for 10 minutes. The sample is then allowed to cool and pH is measured.

d) If the final pH <5.0 then EF-I is selected otherwise, EF-II is selected.

3) Rotary agitation of the solid phase of sample

a) The solid phase is poured in extraction vessels, specially designed for TCLP, along with extraction fluid having volume equal to twenty times the weight of the solid phase and sealed.
b) The vessels are then subjected to continuous end-over-end rotation at (30 ± 2) rpm for (18 ± 2) hours.

For the present study the extraction vessels permit 25.0 gram of sludge with 500 ml of extraction fluid.

4) Filtration of the extract and storage

Following extraction, the liquid extract is separated from the solid phase by positive pressure filtration a 0.6 to .08 μm glass fiber filter with pressure not exceeding 50 psi. The pH of the extract is maintained at less than 2.0 for metal analyses. A more elaborate description of the procedure can be found in EPA Method 1311 (USEPA, 1992a) detail description of the TCLP system employed in this study can be found elsewhere (Badruzzaman, 2003).

The TCLP procedure is generally useful for classifying waste material for disposal options.

A concern has arisen in recent years regarding TCLP analysis in that the test is based on the assumption that the waste material will be buried in landfill along with organic material, however organic matter is rarely buried with other waste anymore (composting usually applies). In light of this issue, other leachate techniques may be more appropriate.

In this study the pH of the sample material is first established in the TCLP procedure, and then leached with an acetic acid / sodium hydroxide solution at a 1:20 mix of sample to solvent. For example, a TCLP jug contains 25g of sample and 500 mL of solution. The leachate mixture is sealed in extraction vessel for general analysis, pressure sealed as in zero-headspace extractions (ZHE) for volatile organic compounds and tumbled for 18 hours to simulate an extended leaching time in the ground. It was then filtered using filter paper so that only the solution (not the sample) remains and this is then analyzed for As, Pb, Cd, Cr, Ni, Hg, Fe and Mn using AAS (Shimadzu AA 6800).

Fig.3.8 Atomic Absorption Spectrophotometer (Shimadzu AA 6800)

3.5 Study Of ETP Treatment Scheme

In the selected industry as mentioned in the previous article ETP treatment scheme was studied thoroughly to register whether any toxicity generating chemicals were used or not. If there is any toxicity generating chemicals, sludge may persist the toxicity resulting unusable in deed.

3.6 Study Of Fertilizer Characteristics

Fertilizer characteristics were studied as in the appendix. There are many types of fertilizers. Fertilizers are basically chemical fertilizers and organic fertilizers. Study of fertilizer characteristics helped to identify the essential nutrients required to be a fertilizer. Different types of crops or plants need different types of nutrients. As per the necessity of plant's nutrients fertilizers are made.

3.7 Comparison of sludge Characteristics to fertilizers

Comparison study was done after studying different type of commercial fertilizer characteristics and the characteristics of sample sludge. Essential characteristics of commercial fertilizer are available in the web site of Ministry of Agriculture (MOA), Bangladesh. Besides this Bangladesh Agricultural Research Council has published Fertilizer Recommendation Guide – 2012.

3.8 Plantation With Different Sludge Soil Mixture

Fig. 3.9 Plantation in soil and biological ETP sludge

The effect of knit dyeing industry ETP sludge on growth of bringal (Solanummelongena) vegetable plant was observed in the month of February, March 2017. Brinjal plantation was done arbitrarily for observation without any rationalization. Different mixing ratios such as 100% soil, 75% soil with 25% sludge, 25% soil with 75% sludge, 50% sludge with 50% soil and 100% sludge were used for plantation. These mixing ratios for plantation were practiced for both biological ETP sludge and biochemical ETP sludge.

Fig. 3.10 Plantation in soil and biochemical ETP sludge

CHAPTER 4
RESULT AND DISCUSSION

4.1 Introduction

The analysis of sludge sample are discussed in this chapter. This chapter expresses the results obtained after laboratory experiment of preselected physical and chemical characteristics of sludge sample. It presents laboratory experiments to determine the characteristics of sludge whether to use as fertilizer or not, heavy metal content in sludge and leaching test results of sludge. This also represents the observation on plantation in different sludge soil mixture.

4.2 Characteristics Of Sludge

Sludge samples were collected for two times from each type of ETP. For the first time experiment was done named SET 1 and second time named SET 2 to differentiate two different sets samples. The samples from biological type ETP were divided in two and designated as B1, B2 for SET1 and B3, B4 for SET 2. Similarly the samples from biochemical type ETP were divided in two and designated asC1, C2 for SET1 and C3, C4 for SET2. Therefore, each set consists of four samples. The four sludge samples were categorized as B1, B2, C1 and C2 for SET1 experiment and B3, B4, C3 and C4 for SET2 experiment. The legend is summarized as in the Table 3.1.

The laboratory experimental results of sludge are in Table 4.1, 4.2, 4.3, 4.4 and 4.5 for set 1.

Table 4.1 Preliminary analysis of knit fabric dyeing industry ETP sludge(SET 1)

Parameter	SLUDGE SAMPLE (SET 1)			
	B1	**B2**	**C1**	**C2**
Specific gravity at 26 C	1.01	1.52	1.06	1.04
Solubility in Water	Insoluble	Insoluble	Insoluble	Insoluble
Color	Black	Black	Brown	Brown
pH	7.6		8.4	
Water Soluble Chloride, (%)	0.21	0.9	0.0236	0.016

Table 4.2 Nonmetal analysis of knit fabric dyeing industry ETP sludge (SET 1)

Parameter	SLUDGE SAMPLE (SET 1)			
	B1	**B2**	**C1**	**C2**
Carbon (%)	18.51	24.94	23.6	23.50
Nitrogen (%)	7.11	5.60	0.70	0.58
Phosphorus (%)	0.59	0.54	0.28	0.29
Sulphur (%)	1.45	1.83	0.42	0.34
Boron (%)	0.08	0.09	0.09	0.15

Table 4.3 Oxides in knit fabric dyeing industry ETP sludge (SET 1)

Parameter	SLUDGE SAMPLE (SET 1)			
	B1	**B2**	**C1**	**C2**
CO_2, (%)	38.0876	42.4065	12.3887	-
SiO2, (%)	24.3611	17.0052	19.1533	21.3610
Fe_2O_3, (%)	17.5397	21.8913	16.9343	20.1606
SO_3, (%)	7.6602	6.5474	3.8685	4.1321
Al_2O_3, (%)	2.0012	1.3737	2.8792	3.1621
ZnO, (%)	1.9579	1.8060	0.0570	0.0717
TiO_2, (%)	1.3840	-	0.2270	
RuO_2, (%)	1.2808	2.8356	0.2571	0.3358
Na_2O, (%)	1.2622	2.9977	1.1569	1.2794
CaO, (%)	1.2310	0.7660	37.1536	42.3995
MgO, (%)	1.1530	0.9023	3.9873	-
P_2O_5, (%)	0.9502	0.6002	0.4575	0.5489
CuO, (%)	0.6026	0.5617	-	
MnO, (%)	0.2184	0.2163	0.0568	0.0647
Cr_2O_3, (%)	0.2023	0.0901	-	0.0563
NiO, (%)	0.1079	-	-	-

Table 4.4 Heavy metals in knit fabric dyeing industry ETP sludge (SET 1)

Parameter	SLUDGE SAMPLE (SET 1)			
	B1	**B2**	**C1**	**C2**
Sodium (Na), ppm	335.000	259.000	125.000	180.000
Potassium (K), ppm	18.600	20.700	12.200	13.200
Calcium (Ca), ppm	110.430	97.500	4456.20	5482.200
Magnesium (Mg), ppm	32.430	39.090	179.6	189.800
Copper (Cu), ppm	2.539	2.142	0.394	0.400
Manganese (Mn), ppm	4.010	4.340	4.34	2.150
Iron (Fe), ppm	77.280	143.900	953.49	1087.130
Arsenic (As), ppm	0.0143	0.008200	0.0444	0.0189
Chromium (Cr), ppm	0.803	0.589	0.103	0.116
Lead (Pb), ppm	0.284	0.290	0.244	0.284

Mercury (Hg), ppm	0.000	0.000	0.00	0.000
Cadmium (Cd), ppm	0.000	0.000	0.00	0.000
Nickel (Ni), ppm	0.169	0.136	0.016	0.046
Zinc (Zn), ppm	11.112	6.951	2.142	2.520

Table 4.5 TCLP test of knit fabric dyeing industry ETP sludge (SET 1)

Parameter	SLUDGE SAMPLE (SET 1)			
	B1	**B2**	**C1**	**C2**
Chromium (Cr), ppm	0.458	2.990	0.022	0.029
Lead (Pb) , ppm	0.158	0.187	0.215	0.227
Cadmium (Cd) , ppm	0.000	0.000	0.000	0.000
Nickel (Ni) , ppm	0.021	0.020	0.013	0.020
Arsenic (As), ppm	0.0223	0.0317	0.0164	0.0114
Mercury (Hg) , ppm	0.000	0.000	0.000	0.000
Iron (Fe) , ppm	45.590	128.27(	7.780	6.080
Manganese (Mn) , ppm	1.470	1.820	1.660	1.620

The laboratory experimental results of sludge are in Table 4.6, 4.7, 4.8, 4.9, and 4.10 for set 2

Table 4.6 Preliminary analysis of knit fabric dyeing industry ETP sludge (SET 2)

Parameter	SLUDGE SAMPLE (SET 2)			
	B3	**B4**	**C3**	**C4**
Specific gravity at 26 C	0.788	0.745	0.606	0.857
Solubility in Water	Insoluble	Insoluble	Insoluble	Insoluble
Color	Dark Ash	Dark Ash	Brown	Brown
pH	8.82	8.1	11.5	9.6
Water Soluble Chloride, (%)	1.48	0.144	0.284	0.056

Table 4.7 Non metal analysis of knit fabric dyeing industry ETP sludge (SET 2)

Parameter	SLUDGE SAMPLE (SET 1)			
	B3	**B4**	**C3**	**C4**
Carbon (%)	14.93	14.67	5.68	3.24
Nitrogen (%)	3.32	4.20	0.70	0.67
Phosphorus (%)	0.46	0.45	0.32	0.27
Sulphur (%)	1.49	1.68	0.55	0.53
Boron (%)	0.69	0.79	0.55	0.32

Table 4.8 Oxides in knit fabric dyeing industry ETP sludge (SET 2)

Parameter	SLUDGE SAMPLE (SET 2)			
	B3	B4	C3	C4
CO_2, (%)	33.0175	29.3119	4.5844	-
SiO2, (%)	24.7633	29.4946	11.4682	10.6042
Fe_2O_3, (%)	5.0529	6.9468	20.9583	19.1283
SO_3, (%)	16.4327	17.7069	1.7066	2.3868
Al_2O_3, (%)	2.2988	2.5326	1.4540	1.0036
ZnO, (%)	0.4747	0.5890	0.0434	0.1250
TiO_2, (%)	0.7702	0.8670	0.2689	0.3362
RuO_2, (%)	0.6903	0.8081	0.3862	0.3696
Na_2O, (%)	2.9776	1.6600	0.7498	0.3097
CaO, (%)	3.5094	3.9644	53.4281	62.0813
MgO, (%)	1.1583	1.2273	3.9101	2.5388
P_2O_5, (%)	2.2801	1.8973	0.3279	0.3478
CuO, (%)	0.1967	0.2149	-	-
MnO, (%)	0.1831	0.1311	0.0804	0.0959
Cr_2O_3, (%)	-	-	-	-
NiO, (%)	0.0364	0.0388	-	-

Table 4.9 Heavy metals in knit fabric dyeing industry ETP sludge (SET 2)

Parameter	SLUDGE SAMPLE (SET 2)			
	B3	B4	C3	C4
Sodium (Na), ppm	118.100	60.100	57.800	15.000
Potassium (K), ppm	15.200	10.400	9.000	1.600
Calcium (Ca), ppm	91.920	109.930	3987.500	4828.800
Magnesium (Mg), ppm	32.590	36.710	225.500	156.300
Copper (Cu), ppm	3.033	3.231	0.266	0.617
Manganese (Mn), ppm	2.880	1.780	2.540	2.400
Iron (Fe) , ppm	67.960	96.160	903.970	622.620
Arsenic (As), ppm	0.0045	0.00138	0.00445	0.0481
Chromium (Cr), ppm	0.364	0.499	0.093	0.162
Lead (Pb), ppm	0.298	0.368	0.197	0.266
Mercury (Hg), ppm	0.000	0.000	0.000	0.000
Cadmium (Cd), ppm	0.010	0.005	Nil	Nil
Nickel (Ni), ppm	0.118	0.122	0.059	0.052
Zinc (Zn), ppm	7.122	8.866	1.223	3.369

Table 4.10 TCLP test of knit fabric dyeing industry ETP sludge (SET 2)

Parameter	SLUDGE SAMPLE (SET 2)			
	B3	**B4**	**C3**	**C4**
Chromium (Cr), ppm	0.067	0.022	Nil	Nil
Lead (Pb), ppm	0.166	0.129	0.179	0.166
Cadmium (Cd) , ppm	0.020	Nil	Nil	Nil
Nickel (Ni), ppm	0.028	0.028	0.003	0.011
Arsenic (As) , ppm	0.0381	0.0135	0.0244	0.0065
Mercury (Hg) , ppm	Nil	Nil	Nil	Nil
Iron (Fe) , ppm	4.050	37.430	1.300	1.230
Manganese (Mn) , ppm	Nil	Nil	Nil	Nil

4.3 Presence of Ca, CaO, Fe is More In Sludge of Biochemical Type ETP Than That of Biological type ETP

It is seen from the literature study that lime and ferrous sulphate are being used in biochemical type ETP as coagulant. For the reason the sludge produced in biochemical type ETP contains more Ca, CaO and Fe than that of biological type ETP.

4.4 Heavy Metals In Sludge vs. Fertilizers

As in the Table 2.10 in chapter 2 the maximum allowable limits of Arsenic (As), Cadmium (Cd), Lead (Pb), Mercury (Hg), Chromium (Cr), Nickel (Ni), Zinc (Zn) and Copper (Cu) in organic fertilizers are 20, 5, 30, 0.1, 50, 30, 0.1, 0.05 ppm respectively and that in chemical fertilizers are 50, 10, 100, 5, 500, 50 , NA, NA according to Fertilizer Recommendation Guide – 2012 by Bangladesh Agricultural Research Council the heavy metals present in both sludge of biological type ETP and biochemical type ETP are within the allowable limits.

4.5 TCLP

It is observed in the laboratory that the TCLP leachates from sludge has very low concentration of chromium, lead, cadmium, nickel, arsenic whereas mercury and manganese are undetectable. The result implied that the re-use of knit dyeing industry sludge as fertilizer is feasible in terms of toxicity.

4.6 Sludge Properties Versus Fertilizer Properties

Commonly used chemical fertilizers are Urea, Ammonium Sulphate, Triple super phosphate, Monoammonium phosphate, Diammonium phosphate, etc.

- It is observed that 14.67 - 24.94% C, 4.2 – 5.6% N, 1.68- 1.83% S, 0.45 – 0.59% P in the sludge of biological type ETP after anaerobic digestion and 3.24 – 23.50% C, 0.58 – 0.67% N, 0.34 – 0.54% S, 0.27 – 0.29% P in the sludge of biochemical type ETP after anaerobic digestion and little amount of other nutrients present.
- That is sludge can be a substitute for about 10% Urea, 25% Ammonium sulphate, 50% Monoammonium phosphate, 25% Diammonium phosphate considering nitrogen as nutrient.
- But considering sulphur as nutrient, biological ETP sludge can be substitute of 7% ammonium sulphate, 100% triple super phosphate, 10% Potassium sulphate, 10% Gypsum whereas biochemical ETP sludge can be substitute of 2% ammonium sulphate, 40% triple super phosphate, 3% potassium sulphate, 3% gypsum.
- Considering phosphorus as nutrient both biological and biochemical type ETP sludge can be a substitute of 3% triple super phosphate, 3% monoammonium phosphate, 3% diammonium phosphate.

Both biological and biochemical type ETP sludge contains a huge amount of calcium that can be used in case of triple super phosphate and gypsum.
For the crops like sugarcane, HYV Rice, wheat and other Rabi crops knit dyeing industry sludge can be alternative source of the fertilizer NPKS (10-15-10-4), NPKS (10-24-17-6), NPKS (10-15-10-4), NPKS (12-16-22-6.5) respectively. Hence the numbers within bracket indicates Nitrogen, P2O5, K2O and Sulfur percentage.

It is observed that both biological and bio-chemical type ETP sludge contains more nutrients than organic fertilizers. As the sludge is not toxic and heavy metals content is within the allowable limit, the sludge can be used where the stated organic fertilizers can be used.

It is observed that 4.2 – 5.6% N, 1.68- 1.83% S, 0.45 – 0.59% P in the sludge of biological type ETP after anaerobic digestion and 0.58 – 3.24% N, 0.34 – 0.54% S, 0.27 – 0.29% P in the sludge of biochemical type ETP after anaerobic digestion and little amount of other nutrients present. That is 25% volume of biological type ETP sludge is enough instead of Cow dung (decomposed), Farmyard manure, Poultry manure (decomposed),Bio-slurry (Cow dung), Bio-slurry (Poultry manure) considering sulphur and phosphorus as nutrient.

4.7 Result of Plantation

Fig. 4.1: Brinjal plantation in soil and biological ETP sludge

Brinjal (Solanummelongena) as vegetable crops plantation was done using different sludge soil mixture. Fig. 4.1 shows the plantation in soil and biological type ETP sludge. Whereas Fig.4.2 shows the plantation in soil and biochemical type ETP sludge. In the both cases 100% soil, 25% soil and 75% sludge, 50% soil and 50% sludge, 25% soil and 75% sludge, 100% sludge was considered for plantation.

Plant's length was recorded on the same date as listed in the following Tables 4.11 and 4.12.

Table 4.11 Plant length using biological ETP sludge with soil at different ratio

	Date → Plant Length ↓	14.02.17	01.03.17	04.03.17	15.03.17	28.03.17	Length increased %
Sludge soil mixture	100% Soil	4.5"	4.9"	5.3"	6"	6.3"	40.00
	75% Soil+ 25%Sludge	6.5"	7"	7.4"	8"	8.3"	27.69
	25% Soil+ 75%Sludge	5.7"	6"	6.3"	6.7"	8.6"	50.88
	100% Sludge	8"	8.3"	8.5"	9.5"	10.1"	26.25

Fig. 4.2 Brinjal plantation in soil and biochemical ETP sludge

Table 4.12 Plant length using biochemical ETP sludge with soil at different ratio

Date → / Plant Length ↓		10.02.17	28.02.17	05.03.17	12.03.17	25.03.17	Length increased %
Sludge soil mixture	100% Soil	5.2”	5.8”	6.1”	6.3”	6.9”	32.7
	75% Soil+ 25%Sludge	5.6”	6.0”	6.5”	6.9”	7.5”	33.9
	25% Soil+ 75%Sludge	4.9”	5.2”	5.8”	6.5”	7.6”	55.1
	100% Sludge	5.5”	5.7”	6.0”	6.1”	6.4”	16.36

4.8 Nutrient for Brinjal (*Solanummelongena*)

It is observed that 4.2 – 5.6% N, 1.68- 1.83% S, 0.45 – 0.59% P in the sludge of biological type ETP after anaerobic digestion and 0.58 – 3.24% N, 0.34 – 0.54% S, 0.27 – 0.32% P in the sludge of biochemical type ETP after anaerobic digestion. It is observed that nutrient composition in the sludge is within the recommendation limit as in Table 4.13 of the nutrient recommendation for brinjal .

Table 4.13:Brinjal (Solanummelongena): Nutrient Recommendation

Soil Analysis Interpretation	**Nutrient Recommendation (Kg/ha)**						**Manure (t/ha)**	
	N	P	K	S	Zn	B	CD or PM	
Optimum	0-40	0-12	0-30	0-5	-	-	5	3
Medium	41-80	13-24	31-60	6-10	0.0-1.0	0.0-0.5		
Low	81-120	25-36	61-90	11-15	1.1-2.0	0.6-1.0		
Very Low	121-160	37-48	91-120	16-20	2.1-3.0	1.1-1.5		

(Source: Fertilizer Recommendation Guide – 2012, BARC, pp 118)

CD : Cow dung, PM : Poultry manure

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Introduction

Bangladesh is a land of agriculture where about 80% people are farmers. Due to infertility or poor fertility of land in many areas farmers suffer a lot. For the reason, there are a huge demand of fertilizers. About 4840000 metric ton fertilizers demand in Bangladesh in the year 2015 - 2016 that costs approximately Tk. 96,800 million . The demand of using fertilizers is increasing day by day. On the contrary, there are more than two hundreds of knit dyeing industry in Bangladesh that produce a huge quantity of sludge that can be used as fertilizers to some extent. In that way we can reduce and reuse sludge and save the environment.

5.2 Conclusion

The main objective of this study was to investigate the reuse potential of knit fabric dyeing industry sludge as fertilizer. The physical and chemical properties of sample sludge collected from biological type and biochemical type effluent plant were found out. The sludge characteristics were compared to that of fertilizers. Growth of plantation was observed in different soil sludge mixtures.

A brief summary of findings of this study are as follows:

1. Two sets sludge sample test results show that knit fabric dyeing industry sludge can be used as fertilizer.
2. It is necessary to fix the proper mixing ratio before using sludge as fertilizer. Mixing ratio depends on the soil characteristics.
3. Sludge disposal volume will be reduced if it is used as fertilizer.

5.3 Limitation Of The Study

There are some limitations of the study that need to be pointed out. The limitations are as below:

- Only two types sludge sample was collected from only two industries. More sample would result more concrete result.
- No test was performed for the soil to know its characteristics before plantation.
- Only growth of plantation was observed, crops or fruits were not observed whether it was healthy or not.
- Only brinjal plant was considered for observation arbitrarily.

5.4 Recommendation For Future Work

- Agriculture remains the most important sector of Bangladeshi economy, contributing 19.6 percent to the national GDP and providing employment for 63 percent of the population. There are a huge demand of fertilizer in Bangladesh due to gradual infertility of land.
- More studies are needed for different type of ETP sludge to investigate the re-use potentiality.
- Need to investigate to achieve ultimate goal that is crops or fruits after plantation. And the crops or fruits must be healthy to consume.
- Industries need to be monitored by regulatory body so that toxic materials cannot be discharged without appropriate treatment.
- Industries that use chemicals to be warned to avoid toxic materials in production process if possible.

REFERENCES

Akhtaruzzaman Md. (2006), Treatment of Textile Liquid Waste, MSc. Engineering Thesis, Civil Engineering Department, Bangladesh University of Engineering And Technology, Dhaka.

Akter Salma (2012), Textile Sludge Disposal Using Incineration Technique, Ph.D. Thesis, Civil Engineering Department, Bangladesh University of Engineering And Technology, Dhaka.

Applied and Environmental Soil Science Volume 2014 (2014), Article ID 752708, pp 12.

Badrun Nessa, Rahman Mostafizur M., Mashura Shammi, Rahman Mohammad A., Chowdhury Tasrina Rabia, Ahmad Mubarak, Uddin Khabir Md., (2016),"Impact of textile sludge on the growth of red amaranth (Amaranthusgangeticus)," International Journal of Recycling of Organic Waste in Agriculture, Vol. 5, pp. 163–172.

Bangladesh Agricultural Research Council, "Fertilizer Recommendation Guide 2012," chap. 5, pp. 48 - 49, Bangladesh, 2012.

Bangladesh Standards and Guidelines for Sludge Management :Published by Department of Environment (DoE), Ministry of Environment and Forests, Date February 2015.

Baskar, R., Begum, K.M.M.S., and Sundaram, S., (2006). Characterization and Reuse of Textile Effluent Treatment Plant Waste Sludge in Clay Bricks. J. Univ. Chem. Technol. Metall. 41, 473–478.

Balasubramanian J, Sabumon P.C, Lazar John U., R. Ilangovan (2006), "Reuse Of Textile Effluent Treatment Plant Sludge In Building Materials", Science Direct, Waste Management 26 (2006) 22–28.

Batchelor, W. (1999), "Inorganic Leaching Science", Proceedings of the Environmental Protection Agency", Public Meeting on Waste Leaching, Session III - Leaching Science, USEPA, USA, July 22-23, 1999.

Catherine N. Mulligan and Mehdi Sharifi-Nistanak (2016) , "Conversion of sludge from a wastewater treatment plant to a fertilizer", Int. J. of GEOMATE, Vol.00, No.00 (Sl. No. 00), pp. 00-00 and Env., ISSN:2186-2982(P), 2186-2990(O), Japan International Journal of GEOMATE, July, 2016, Vol. 11, Issue 23, pp. 2194-2199 Geotec., Const. Mat. &Env., ISSN: 2186-2982(Print), 2186-2990(Online), Japan.

Chen, M., and Lena, Q. (2000), “Comparison of Three Aqua Regia Digestion Methods for Twenty Florida Soils”, University of California, Department of Land, Air and Water Resources, One Shields Ave., Davis, Soil Sci. Soc. Am. J. 65:499–510 (2001).

Chilton, J. and Kinniburgh, D. (2003), Soil and Groundwater Protection in the South-East Asia Region, Water Resource Journal, ESCAP, UN, December 2003, Vol. 215, pp.87-94.

Davis Mackenzie L., Cornwell David F. (1998), “Introduction To Environmental Engineering”, McGraw-Hill, chap. 5, pp 442, Singapore.

Eckenfelder, Jr.,W. Wesley (1989), Industrial Water Pollution Control, International Edition, McGraw-Hill Publications, pp. 351-352.

Ghanizadeh Gh and Sarrafpour R (2001), “The Effects of Temperature and pH on Settlability of Activated Sludge Flocs”, Iranian J. Publ. Health, Vol. 30, Nos. 3-4, PP. 139-142.

Guide for Assessment of Effluent Treatment Plants, Department of Environment, Ministry of Environment and Forest, Bangladesh, June 2008.

Hammer Mark J and Jr.Hammer Mark J (2012), Water and Waste Water Technology, Seventh Edition, pp 337-338, Delhi.

Hartwell, S. (1999), Overview of Current Approaches, Proceedings of the Environmental Protection Agency, Public Meeting on Waste Leaching Session III: Leaching Science, USEPA, USA, July 22-23, 1999.

Hazardous waste management in Bangladesh: A country inventory. Published by Department of Environment, Ministry of Environment and Forest, Bangladesh; 2010.

Hoque, A., Clarke, (2010)A., MacDonald, A. (2014), “Implementing a Developing Country’s Global Environmental Commitments: Industry Perspectives on Potential Pollution Prevention Programs in Bangladesh”, School of Environment, Enterprise and Development (SEED), University of Waterloo.

Hossain, A. M. (2004), Stabilization of Heavy Metals in Industrial Sludge with Concrete Mix, M.Sc. Thesis, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh.

Islam M.M., Halim M.A., Islam Saiful M., Islam Safiqul M. and Biswas C.K. (2009), “ Analysis the Plant Nutrients and Organic Matter in Textile Sludge in Gazipur, Bangladesh”, Journal of Environmental Science and Technology 2(1): 63-67,2009, ISSN 1994-7887.

Karia G.L. and Christian R.A. (2013), “ Wastewater Treatment Concepts and Design Approach”, Prentice Hall Of India Private Ltd., New Delhi.

Kimmel, T. (1999), Background of the Toxicity Characteristics Leaching Procedure (TCLP), Proceedings of the Environmental Protection Agency, Public Meeting on Leaching, Session I- Introduction and Overview, USEPA, USA.

Kulkarni Dr.Sunil J. , Abhishek T. Sose , Meera T.Sose (2017), "Characterization of Sludge and Design of Activated Sludge Process for Sewage Treatment", IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) e-ISSN: 2319-2402, p- ISSN: 2319-2399.Volume 11, Issue 9 Ver. I ,PP 20-25.

Macros Von Sperling, Carlos Agusto de Lemos Chernicharo (2007), " Sludge Treatment and Disposal" Biological Waste Water Treatment Series, Volume VI, Published by IWA publishing, UK.

Maddumapatabandi T. D, Silva de W. R. M., Silva de K. M. N. (2011), "Analysis of Textile Sludge to Develop a Slow Releasing Organic Fertilizer," SAITM Research Symposium on Engineering Advancements (SAITM – RSEA 2014), pp. 79 - 82.

Martin, S., and Griswold, W. (2009), "Human Health Effects of Heavy Metals", Center for Hazardous Substance Research, Issue 15, March 2009.

Mary Lissy P N, Dr. M S Sreeja (2014), "Utilization of sludge in manufacturing Energy Efficient Bricks", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , Volume 11, Issue 4 Ver. III (Jul- Aug. 2014), pp. 70-73.

McGhee, T.G. (1991), Water Supply and Sewerage, 6th Edition, McGraw-Hill Book Co., Singapore, pp. 401-402, 491-492, 514,547.

McGonigle T. P, Beauchamp E. G, Evans L. J. and Wells C. J. (2012), "Mineralization and Crop Uptake of Nitrogen from Textile Manufacturing Wastewater Sludge Cake", Applied and Environmental Soil Science, Hindawi Publishing Corporation, Volume 2012, Article ID 273456, PP.1-10.

Mehari MuuzWeldemariam (2014), "Heavy Metal (Pb, Cd, Zn, Cu, Cr and Fe) Content in Almeda Textile Industry Sludge, Northern Tigrai, Ethiopia," International Journal of Scientific and Research Publications, Volume 4 (Issue 1), pp. 1 – 3.

Metcalf & Eddy (2003), Waste Water Engineering Treatment and Reuse, Tata McGraw-Hill, Fourth Edition, chap. 14, pp. 1449, New Delhi.

New Jersey Sludge Sampling and Analytical Guidance Document, New Jersey Department of Environmental Protection Division of Water Quality Bureau of Pretreatment and Residuals, January 2012.

Noble, R (March 2011). Risks and benefits of soil amendment with composts in relation to plant pathogens. Australasian Plant Pathology. 40 (157). Retrieved 9 July 2018.

Parameswari M. and Udayasoorian C (2013). "Evaluation of Textile and Dye Industry Liquid and Solid Waste and Amendments on Exchangeable Magnesium Content of Soil Under Sunflower Crop", Journal Of Environmental Science And Sustainability (JESS) 1(3): 89-92,Tamilnadu, India.

Parameswari M. and Udayasooriyan C. (2013), "Vermicomposting of textile and dye sludge with carbonaceous materials and its carbon and nitrogen status," Journal of Environmental Science and Sustainability (JESS,) Vol.1 (3), pp. 93 – 96, India.

Paola Foladori, Gianni Andreottola, Giuliano Ziglio (2010), " Sludge Reduction Technologies in Waste Water Treatment Plants", published by IWA Publishing.

Peavy, H. S., Rowe, D. R., and Tchobanoglous, G. (1985), Environmental Engineering, International Edition, McGraw-Hill Publications, pp. 55-71.

Peavy H.S., Rowe D. R., and Tchobanoglous George (1985); Environmental Engineering, International Edition, McGraw-Hill Publications, chap. 5, pp 292.

Rahman M. Habibur, Al-Muyeed Abdullah (2010), Solid and Hazardous Waste Management, Published by ITN-BUET, chap.9, pp 291.

Rajkumar N, "Reuse of Textile ETP Sludge as Construction material"(2011), Lecturer, Department of Civil Engineering, Kongu Engineering College, Perundurai, Erode.

RaghunathanT,Gopalsamy P, Elangovan.R (2010), "Study on Strength of Concrete with ETP Sludge from Dyeing Industry", International Journal Of Civil And Structural Engineering, Volume 1, No. 3.

Rittmann Bruce E., McCarty Perry L.(1982), Environmental Biotechnology: Principles And Applications, McGraw-Hill Publications, chap. 15, pp 719.

Ruqia Nazir, Muslim Khan, Muhammad Masab, Hameed Ur Rehman, Naveed Ur Rauf, SurryaShahab, NosheenAmeer, Muhammad Sajed, MohibUllah, Muhammad Rafeeq, ZeenatShaheen (2015), "Accumulation of Heavy Metals (Ni, Cu, Cd, Cr, Pb, Zn, Fe) in the soil, water and plants and analysis of physico-chemicalparameters of soil and water Collected from Tanda Dam kohat", Journal of Pharmaceutical Science and & Research Vol. 7(3), pp89-97.

Saha, P. K., and Hossain, M.D. (2011), “Assessment of Heavy Metal Contamination and Sediment Quality in the Buriganga River, Bangladesh”, Bangladesh University of Engineering & Technology.

Shivanath G, E. Arumugam 1 and Murugesan V (2011), “Utilization Of Industrial Effluent Treatment Plant (Etp)Sludge As Partial Replacement For Cement In Concrete”,Jr. of Industrial Pollution Control 27(1)(2011),pp 33-38, India.

Shrikant S Jahagirdar, S. Shrihari, B. Manu (2013), “Reuse of textile mill sludge in burnt clay bricks”, International Journal of Advanced Technology in Civil Engineering, Volume-2, Issue-1, India.

Soil Science Society of America. Retrieved May 10,2012.

Tchobanoglous G., Burton F.L., Stensel H.D. (2003) Wastewater Engineering: Treatment and Reuse. Inc. Metcalf & Eddy, McGraw-Hill, 4th edition.

The Environment Conservation Rules, 1997.

Thomson, J.C., Azariah, J., and Viji, A.G.R., (1999), “Impact of textile industries on RiverNoyyal and riverine groundwater quality in Tirupur”, India. Environ. Monit.Assess. 18, 359–368.

Touhid Bin Anwar, BushraBehrose, Shoeb Ahmed (2018), “Utilization of textile sludge and public health risk assessment in Bangladesh”, Sustainable Environment Research, 28 (2018) 228-233.

United States Department of Agriculture “Heavy Metal Soil Contamination”, Urban Technical Note No. 3, September, 2000.

USEPA, (1992).Toxicity Characteristic Leaching Procedure (TCLP). Standard SW-864, Method 1311, US Environmental Protection Agency, Washington D.C.

USEPA, (1998). Identification and Listing of Hazardous Waste, Title 40 Code Federal Regulations (CFR).Part 261, App VIII (Chapter 1).US EnvironmentalProtection Agency, Washington D.C.

Waste Concern (2010), “Hazardous Waste Management in Bangladesh: A Country Inventory”, Published by Department of Environment (DOE), Ministry of Forestry and Environment, Dhaka, Bangladesh, October, 2010.

Wikipedia wet processing engineering

http: //fashion2apparel.blogspot.com/2017/04/textile-chemicals-auxilaries.html;

http://textilelearner.blogspot.com/2013/04/major-chemicals-used-in-textile-wet.html

www.textiletoday.com.bd/managing-textile-sludge-sustainability

www.bkmea.com

www.btmadhaka.com

www.nationsencyclopedia.com/economies/Asia-and-the-Pacific/Bangladesh-AGRICULTURE.html#ixzz5XeskiJzE

www.moa.gov.bd

www.epa.gov/ epaoswer/hazwaste/test/faqs

APPENDIX - A

Classification of Sludge

Depending on the origin of the wastewater sludge can be classified as:

Category A: Municipal sludge including comparable sludge
Category B: Sludge from industry including sludge from CETP
Category C: Sludge from industry including sludge from CETP belonging to the category of hazardous waste.

In cases where wastewater producing a sludge classified as Category C is mixed with other types of wastewater and treated together, for example in a CETP, the resulting sludge is to be classified as Category C. In cases where wastewater producing a sludge classified as Category B is mixed with wastewater producing sludge classified as Category A and treated together, the resulting sludge is to be classified as Category B. If different classes of sludge are mixed during collection, transport, treatment or other stages of sludge management, the method of classification described above is to be applied.

Category A + Category B = Category B
Category A + Category C = Category C
Category B + Category C = Category C
Category A + Category B + Category C = Category C

Depending on the classification of the sludge different management options are permissible. An overview and detailed requirements regarding the management options are presented in later.

To facilitate classification of a specific sludge the criteria and the steps to be followed to classify are described on the following pages. In view of the protection of the environment, it is forbidden to mix Category A sludge with Category C sludge.

Table A-1: Management options per waste class

Management option	Waste class		
	A	**B**	**C**
Anaerobic digestion (co-fermentation)	X[1]	X[1]	**
Anaerobic digestion (composting)	X[1]		
Agricultural use	X		
Controlled landfill	X	X	X
Thermal incineration	X[1]	X[1]	X[1]
Land application (filling material e.g. for food prevention)	X	X[2]	**
Recycling in brick, cement or asphalt making)	X	X[3]	**

[1]Residues will remain that have to be disposed of, fulfilling the requirements applicable to the category, on an alternative route e.g. by landfill
[2]Innert material (low organic matter required)

[3]Availabilty and capacity limited by local conditions. Accepted sludge volume limited due to a loss of compressibility of the product.
[*]Requirements for the landfill class vary depending on category of sludge. **The producer may provide evidence that sludge categorized as category C sludge does not possess any hazardous characteristics; in this case it may be categorized as category B sludge and the management options of anaerobic digestion (co-fermentation), land application (filling material e.g. for flood prevention), recycling in brick, cement or asphalt making are permissible.

Description of management options including design parameter

Anaerobic digestion (biogas recovery)

It may be beneficial to add sludge from the biological treatment based on activated sludge treatment to an anaerobic digestion plant or conduct co-fermentation with municipal sewage sludge and other suitable materials to collect biogas for energy production and save emissions. In addition, nutrients in the residue can be used as a fertilizer if the input materials all may be used in agriculture.

Especially when sludge from industries are used, it is necessary to keep in mind, that some substances may have an inhibiting effect on the microorganisms to optimize the digestion process. The inhibitors commonly present in anaerobic digesters include ammonia, sulfide, light metal ions, heavy metals, and organics.

For reasons of climate protection the organic matter in the residue should be as low as possible to prevent uncontrolled biodegradation leading to emissions and leachate when it is used in landfill application. Requirements for landfill application are described in Table A-3.

Anaerobic digestion is not permissible for Category C sludge from hazardous industries/CETP in any case as the risk of toxic substances causing emissions that are harmful for human beings and the environment is high.

Aerobic digestion (composting)

Composting can be used to produce fertilizer for application in agriculture. To gain a suitable compost, carbon-rich material is required and an optimized C:N ratio would be 25 – 30:1. As not all sludge ensures this ratio, so co-composting material like green waste, sawdust, woodchip, rice and straw can be added. The major advantages of promoting composting are an increase of the C:N, a reduction of salt, heavy metal and leaching of hazardous and (phyto-) toxic substances.

Therefore, this option should be prohibited for the use of hazardous waste (Category C) and even for non-hazardous waste from industries (Category B) when the product is intended to be used in agriculture.

Agricultural use

Table A-2: Parameter limits of sludge for use as compost/fertilizer

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

*Soil of the agricultural land before application of sludge

The quantity is limited:
< 3 t dry substance sewage sludge per ha in 3 years
< 10 t dry substance sludge compost per ha in 3 years

Controlled Landfill

Controlled landfill describes the possibility to deposit the sludge in the ground. 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.
The sludge has to be stabilized by reducing the organic fraction to prevent uncontrolled degrading processes. To have a better control of greenhouse emissions(methane) and leachate, the waste (sludge) has to be deposited in dedicated landfill sites.
Categories exist for different kinds of waste depending on its hazardous potential or pollutants, which have different requirements for the construction, the pollutants(measure in leachate) and monitoring.

Basic requirements for the location of a landfill site:

- The over flooding level should be > 2.0 m of the maximum expected water level ofthe 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

Controlled landfill sites in Bangladesh are proposed to be categorized in 3 classes, inert landfill (class 0), non-hazardous landfill (class 1 and class 2) and hazardous landfill(class 3)depending on requirements for the acceptance of waste and for the construction. The definition of the landfill classes for the purpose of this document is based on the types of waste (i.e. inert, non-hazardous and hazardous) that may be accepted and the binding limit values the waste in question must comply with. These are listed in Table A-3. It is recommended that the operator shall maintain a list of approved wastes that can be disposed.

Table A-3: Landfill classes[3]

Designation	Unit	Landfill class 0 (Inert)	Landfill class 1 (non hazardous)	Landfill class 2 (non hazardous)	Landfill class 3 (hazardous and non hazardous)
Investigation on original substance					
Water soluble part	%	0.4	3	6	10
Extractable lipophilic substances	%	0.1	0.4	0.8	4
Total BTEX[4]	mg/kg d.s	6			
Total PCB'S[5]	mg/kg d.s	1			
Total PAK'S[6]	mg/kg d.s	30			
MKW[7] C_{10}-C_{40}	mg/kg d.s	500			
Acid neutralization capacity	mmol/kg				
Calorific	KJ/Kg	6000	6000	6000	6000
Breathability (AT_4[8])	mg/g O_2 d.s.	5	5	5	5

[3]Landfill class 0,1,2 and 3 are over ground sites characterized by types of wastes (i.e. inert, non-hazardous and hazardous) and its limiting values allowed to be disposed as provided in the table.
[4]BTEX= Benzol, Toluol, Ethylbenzol and ortho-xylol
[5]PCB= Polychlorinated bipheny
[6]PAK= Polycyclic aromatic hydrocarbons
[7]MKW=Petroleum-derived hydrocarbon
[8]AT_4= Breathability according to DIN ISO 16072

Designation	Unit	Landfill class 0 (Inert)	Landfill class 1 (non hazardous)	Landfill class 2 (non hazardous)	Landfill class 3 (hazardous and non hazardous)
Investigation on original substance					
Total organic carbon (TOC)	%	1	1	3	6
Loss on ignition 550^{0}C	%	3	3	5	10
Leachate with ditilled water					
pH*	mg/l	5.5-13	5.5-13	5.5-13	4.0-13
Weak acid dissociable cyanide	mg/l	0.1	0.1	0.5	1
Fluoride (F)	mg/l	1	5	15	50
Phenols	mg/l	0.1	0.2	50	100
Dissolved organic carbon(DOC)**	mg/l	50	50	80	100
Arsenic (As)	mg/l	0.05	0.2	0.2	2.5
Lead (Pb)	mg/l	0.05	0.2	1	5
Cadmium (Cd)	mg/l	0.004	0.05	0.1	0.5
Copper (Cu)	mg/l	0.2	1	5	10
Nickel (Ni)	mg/l	0.04	0.2	1	4
Mercury (Hg)	mg/l	0.001	0.005	0.02	0.2
Zinc (Zn)	mg/l	0.4	2	5	20
Barium (Ba)	mg/l	2	5	10	30
Chromium (Cr), total	mg/l	0.05	0.3	1	7
Molybdenum (Mo)	mg/l	0.05	0.3	1	3
Antimony (Sb)***	mg/l	0.006	0.03	0.07	0.5

Antimony Co Value	mg/l	0.01	0.12	0.15	1
Selenium (Se)	mg/l	0.01	0.03	0.05	0.7
Chloride (Cl)	mg/l	80	1500	1500	2500
Sulphate (SO_4)****	mg/l	100	2000	2000	5000

*Divergent pH values alone not represent an exclusion criterion. Where pH values are too high or too low, the cause shall be examined.
**The allocation value for DOC shall also be satisfied if the waste or the landfill replacement construction material fails to satisfy the allocation value at its own pH value, but does satisfy the allocation value at a pH value between 7.5 and 8.0 with the approval of the competent authority, excessive values of DOC up to 200 mg/l shall be permissible if the public welfare is not impaired and up to max.300 mg/l if they are based on inorganically bound carbon.
***Antimony values that exceed the values given for "Antimony(Sb)" shall be permissible if the Concentration value of the percolation test provided for "Antimony Co values" is not exceeded.
****Excessive sulphate values up to 600 mg/l shall be permissible if the Co value of the percolation test does not exceed 1,500 mg/l where the liquid/solid ratio=0.1 l/kg.

Source: Bangladesh Standards and Guidelines for Sludge Management, Department of Environment (DoE), Ministry of Environment and Forests, February 2015.

APPENDIX - B

Effect of heavy metal toxicity on plants.

Heavy metal	Plant	Toxic effect on plant
As	Rice (Oryza sativa)	Reduction in seed germination; decrease in seedling height; reduced leaf area and dry matter production
	Tomato (Lycopersiconesculentum)	Reduced fruit yield; decrease in leaf fresh weight
	Canola (Brassica napus)	Stunted growth; chlorosis; wilting
Cd	Wheat (Triticum sp.)	Reduction in seed germination; decrease in plant nutrient content; reduced shoot and root length
	Garlic (Allium sativum)	Reduced shoot growth; Cd accumulation
	Maize (Zea mays)	Reduced shoot growth; inhibition of root growth
Co	Tomato (Lycopersiconesculentum)	Reduction in plant nutrient content
Cr	Mung bean (Vignaradiata)	Reduction in antioxidant enzyme activities; decrease in plant sugar, starch, amino acids, and protein content
	Radish (Raphanussativus)	Reduction in shoot length, root length, and total leaf area; decrease in chlorophyll content; reduction in plant nutrient content and antioxidant enzyme activity; decrease in plant sugar, amino acid, and protein content
	Wheat (Triticum sp.)	Reduced shoot and root growth
	Tomato (Lycopersiconesculentum)	Decrease in plant nutrient acquisition
	Onion (Allium cepa)	Inhibition of germination process;

		reduction of plant biomass
Cu	Bean (Phaseolus vulgaris)	Accumulation of Cu in plant roots; root malformation and reduction
	Black bindweed (Polygonum convolvulus)	Plant mortality; reduced biomass and seed production
	Rhodes grass (Chlorisgayana)	Root growth reduction
Hg	Rice (Oryza sativa)	Decrease in plant height; reduced tiller and panicle formation; yield reduction; bioaccumulation in shoot and root of seedlings
	Tomato (Lycopersiconesculentum)	Reduction in germination percentage; reduced plant height; reduction in flowering and fruit weight; chlorosis
Mn	Broad bean (Viciafaba)	Mn accumulation shoot and root; reduction in shoot and root length; chlorosis
	Spearmint (Menthaspicata)	Decrease in chlorophyll a and carotenoid content; accumulation of Mn in plant roots
	Pea (Pisumsativum)	Reduction in chlorophylls a and b content; reduction in relative growth rate; reduced photosynthetic O_2 evolution activity and photosystem II activity
	Tomato (Lycopersiconesculentum)	Slower plant growth; decrease in chlorophyll concentration
Ni	Pigeon pea (Cajanuscajan)	Decrease in chlorophyll content and stomatal conductance; decreased enzyme activity which affected Calvin cycle and CO_2 fixation
	Rye grass (Loliumperenne)	Reduction in plant nutrient acquisition; decrease in shoot yield; chlorosis
	Wheat (Triticum sp.)	Reduction in plant nutrient acquisition
	Rice (Oryza sativa)	Inhibition of root growth
Pb	Maize (Zea mays)	Reduction in germination percentage; suppressed growth; reduced plant biomass;

		decrease in plant protein content
	Portia tree (Thespesiapopulnea)	Reduction in number of leaves and leaf area; reduced plant height; decrease in plant biomass
	Oat (Avena sativa)	Inhibition of enzyme activity which affected CO_2 fixation
Zn	Cluster bean (Cyamopsistetragonoloba)	Reduction in germination percentage; reduced plant height and biomass; decrease in chlorophyll, carotenoid, sugar, starch, and amino acid content
	Pea (Pisumsativum)	Reduction in chlorophyll content; alteration in structure of chloroplast; reduction in photosystem II activity; reduced plant growth
	Rye grass (Loliumperenne)	Accumulation of Zn in plant leaves; growth reduction; decrease in plant nutrient content; reduced efficiency of photosynthetic energy conversion

(Source: Applied and Environmental Soil Science Volume 2014 (2014), Article ID 752708, pp12)

APPENDIX – C

Fertilizer Specifications

Specifications of different type of fertilizers are listed below:

1. Ammonium Sulphate

(i)	Ammoniacal nitrogen, percent by weight, minimum	21.10
(ii)	Sulphur (as SO_4-S), percent by weight, minimum	23.50
(iii)	Moisture, percent by weight, maximum	1.00
(iv)	Free acidity (H_2SO_4), percent by weight, maximum (0.04% for materials obtained from by-product ammonia and by-product gypsum)	0.025
(v)	Arsenic (as AS_2O_2), percent by weight, maximum	0.01

2. Urea (free flowing)

(i)	Total nitrogen, percent by weight (on dry basis), minimum	46.00
(ii)	Biuret, percent by weight, maximum	1.50
(iii)	Moisture, percent by weight, maximum	1.00
(iv)	Particle size-90 percent of the material shall pass through 2.8 mm sieve and not less than 80% by weight, shall be retained on minimum 1mm IS sieve except NGFF granules which shall be retained on minimum 0.5 mm IS sieve.	

3. Urea (coated granular)

(i)	Total nitrogen, percent by weight, content with coating, minimum	46.00
(ii)	Biuret, percent by weight, maximum	1.50
(iii)	Moisture, percent by weight, maximum	0.50
(iv)	Particle size- Minimum 90 percent of the material shall pass through 4mm IS sieve and shall be retained on 2mm IS sieve.	

4. Single Super Phosphate

(i)	Water soluble phosphates (as P_2O_5), percent by weight, minimum	16.00
(ii)	Total sulphur, percent by weight, minimum	10.00
(iii)	Total calcium, percent by weight, minimum	18.00
(iv)	Free phosphoric acid (as P_2O_5), percent by weight, maximum	3.00
(v)	Moisture, percent by weight, maximum (Powder)	8.00

5. Triple Super Phosphate

(i)	Total Phosphates (as $P_2 O_5$), percent by weight, minimum	46.00
(ii)	Water solube phosphates (as $P_2 O_5$), percent by weight, minimum	40.00

(iii)	Free phosphoric acid (as P_2O_5), percent by weight, minimum	3.00
(iv)	Moisture, percent by weight, maximum	5.00

6. Rock Phosphate

(i)	Total Phosphates (as P_2O_5), percent by weight, minimum	28.00
(ii)	Particle size- Minimum 90 percent of the materials shall pass through 0.15mm IS sieve and the balance 10 percent of materials shall pass through 0.25mm IS sieve.	

7. Potassium Chloride (Muriate of Potash)

(i)	Total potash content (as K_2O), percent by weight, minimum	60.00
(ii)	Sodium as NaCl percent by weight(on dry basis), minimum	3.50
(iii)	Moisture, percent by weight, maximum	0.50
(iv)	Particle size- 95 percent of the material shall pass through 1.7mm IS sieve and be retained on 0.25mm IS sieve.	

8. Potassium Sulphate

(i)	Total potash content (as K_2O), percent by weight, minimum	50.0
(ii)	Sulphur (as SO_4-S), percent by weigh, minimum	17.0
(iii)	Total Chlorides (as CI) percent by weight, (on dry basis), maximum	2.5
(iv)	Sodium as NaCI, percent by weight, (on dry basis), maximum	2.0
(v)	Moisture, percent by weight, maximum	1.5

9. Gypsum/Phosphogypsum

(i)	Total sulphur, percent by weight, minimum	16.0
(ii)	Total calcium, percent by weigh, minimum	20.0
(iii)	Moisture, percent by weight, maximum	13.0
(iv)	Solubility	Sparingly soluble

10. Diammonium Phosphate (18-46-0)

(i)	Total nitrogen all in ammoniacal form, percent by weight, minimum	18.00
(ii)	Total phosphates (as P_2-O_5), percent by weigh, minimum	46.00
(iii)	Water soluble phosphates (as P_2-O_5), percent by weigh, minimum	41.00
(iv)	Moisture, percent by weight, maximum	1.00
(v)	The material shall be in the form of free-flowing granules	
(vi)	Particle size- Minimum 90 percent of the material shall pass through 4mm BDS sieve and be retained on 1mm BDS sieve. Not more than 5 percent should be below	

1mm sieve.

11. Zinc Sulphate (monohydrate, granular grade)

(i)	Total Zinc content, percent by weight, minimum	36.00
(ii)	Water soluble zinc as percent of total zinc, minimum	95.00
(iii)	Sulphur (as SO_4-S), percent by weigh, minimum	17.00
(iv)	Moisture content (free water), percent by weight, maximum	2.00
(v)	Particle size-90 percent of the material shall pass through 4-2mm IS sieve	
(vi)	Physical condition	Granular, free flowing

12. Zinc Sulphate (Heptahydrate)

(i)	Total Zinc content, percent by weight, minimum	21.00
(ii)	Water soluble zinc as percent of total zinc, minimum	95.00
(iii)	Sulphur (as SO_4-S), percent by weigh, minimum	10.50
(iv)	Magnesium (Mg), percent by weight, maximum	1.00
(v)	Copper (Cu), percent by weight, maximum	0.10
(vi)	pH	Not less than 4
(vii)	Matter insoluble in water, percent by weight, maximum	1.00
(viii)	Moisture content (free water), percent by weight, maximum:	(a)Crystalline 3.0 (b)granular 5.0
(ix)	Particle size (in case of granular product)-90 percent of the material shall pass through 3-1mm BDS sieve.	
(x)	Physical condition	Granular, free flowing/Crystalline

13. Chelated Zinc

(i)	Total Zinc content, percent by weight, minimum	10.00
(ii)	Moisture, percent by weight, maximum	7.00
(iii)	Physical condition	Pale yellow amorphous powder/crystalline
(iv)	pH	Not less than 5.0

14. MagneiumSulphate

(i)	Total magnesium, percent by weight, minimum	3.00
(ii)	Sulphur (as SO_4-S), percent by weight, minimum	12.50
(iii)	Physical condition:	White crystalline powder

15. Solubor (Boron)

(i)	Total boron content, percent by weight, minimum	20.0000
(ii)	Lead, percent by weight, Maximum	0.0005
(iii)	Arsenic percent by weight, Maximum	0.0004
(iv)	Physical condition	White amorphous powder

16. Boric Acid

(i)	Total boron content, percent by weight, minimum	17.0000
(ii)	Lead, percent by weight, Maximum	0.0015
(iii)	Arsenic, percent by weight, Maximum	0.0008
(iv)	Solubility in gams per 100ml of hot water	39.1000
(v)	Sparingly solube in cold water	
(vi)	Physical condition	White crystalline powder
(vii)	pH	Minimum 3.4

17. Sodium Molybdate

(i)	Total molybdenum content, percent by weight, minimum	39.0
(ii)	Physical condition	White crystalline powder
(iii)	pH:	Minimum 8.7

18. TYGER-90 SulpherBentonitePastil Fertilizer

(i)	Sulphur (Minimum)	90%
(ii)	Bentonite (Maximum)	10%
(iii)	Cadium (Maximum)	0.02 mg/kg
(iv)	Lead (Maximum)	1.3 mg/kg
(v)	Arsenic (Maximum)	0.005 mg/kg
(vi)	Other properties	Not combustible

19. WOKOZIM CROP+

(i)	Colour	Dark to Brown
(ii)	pH:	3.5 to 7.0
(iii)	Sp Gravity	1.02 to 1.3
(iv)	Total Nitrogen	5.2% to 6.2%
(v)	Iron	0.05% to 0.15%
(vi)	Copper	0.03% to 0.09%
(vii)	Zinc	0.05% to 0.15%

(viii)	Manganese	0.05% to 0.15%

20. <u>NPKS(8-20-14-5) for HYV Rice</u>

(i)	Total Nitrogen (preferably ammonium form), percent by weight, minimum	20.00
(ii)	Neutral ammonium citrate soluble phosphates (as $P_2 O_5$) percent by weight, minimum	14.00
(iii)	Water soluble potash (as $K_2 O$), percent by weight, minimum	5.00
(iv)	Total sulphur percent by weight, minimum	4.00
(v)	Water soluble sulphate (as SO_4-S), percent by weight, minimum	3.00
(vi)	Moisture, percent by weight, maximum	(a) Powder 3.0 (b) Granular 2.0
(vii)	Particle size: 90 precentot the material shall pass through 4mm IS sieve and not more than 5 percent shall pass through 1mm IS sieve	
(viii)	Physical condition	Granular/Poweder

21. <u>NPKS(10-15-10-4) for Sugarcane</u>

(i)	Total Nitrogen, percent by weight, minimum	10.00
(ii)	Neutral ammonium citrate soluble phosphates (as $P_2 O_5$) percent by weight, minimum	15.00
(iii)	Water soluble potash (as $K_2 O$), percent by weight, minimum	10.00
(iv)	Total sulphur, percent by weight, minimum	4.00
(v)	Water soluble sulphate (as SO_4-S), percent by weight, minimum	3.50
(vi)	Moisture, percent by weight, maximum	(a) Powder 3.0 (b) Granular 2.0
(vii)	Particle size: 90 precentot the material shall pass through 4mm IS sieve and not more than 5 percent shall pass through 1mm IS sieve	
(viii)	Physical condition	Granular/Poweder

22. <u>NPKS(10-24-17-6,0) HYV Rice</u>

(i)	Total Nitrogen, (preferably ammonimum form), percent by weight, minimum	10.00
(ii)	Neutral ammonium citrate soluble phosphates (as $P_2 O_5$) percent by weight, minimum	24.00
(iii)	Water soluble potash (as $K_2 O$), percent by weight, minimum	17.00
(iv)	Total sulphur, percent by weight, minimum	6.00

(v)	Water soluble sulphate (as SO_4-S), percent by weight, minimum	5.00
(vi)	Moisture, percent by weight, maximum	(a) Powder 3.0 (b) Granular 2.0
(vii)	Particle size: 90 precentot the material shall pass through 4mm IS sieve and not more than 5 percent shall pass through 1mm IS sieve	
(viii)	Physical condition	Granular/Poweder

23. <u>NPKS(12-16-22-6.5) for Wheat & other Rabi crops</u>

(i)	Total Nitrogen, percent by weight, minimum	12.00
(ii)	Neutral ammonium citrate soluble phosphates (as $P_2 O_5$) percent by weight, minimum	16.00
(iii)	Water soluble potash (as $K_2 O$), percent by weight, minimum	22.00
(iv)	Total sulphur, percent by weight, minimum	6.50
(v)	Water soluble sulphate (as SO_4-S), percent by weight, minimum	5.50
(vi)	Moisture, percent by weight, maximum	(a) Powder 3.0 (b) Granular 2.0
(vii)	Particle size: 90 precentot the material shall pass through 4mm IS sieve and not more than 5 percent shall pass through 1mm IS sieve	
(viii)	Physical condition	Granular/Poweder

24. <u>NPKS (14-22-15-6) For Sugarcane</u>

(i)	Total Nitrogen, percent by weight, minimum	14.0
(ii)	Neutral ammonium citrate soluble phosphates (as $P_2 O_5$) percent by weight, minimum	22.0
(iii)	Water soluble potash (as $K_2 O$), percent by weight, minimum	15.0
(iv)	Total sulphur, percent by weight, minimum	6.0
(v)	Water soluble sulphate (as SO_4-S), percent by weight, minimum	5.0
(vi)	Moisture, percent by weight, maximum	(a) Powder 3.0 (b) Granular 2.0
(vii)	Particle size: 90 precentot the material shall pass through 4mm IS sieve and not more than 5 percent shall pass through 1mm IS sieve	
(viii)	Physical condition	Granular/Poweder

25. Name of the Product: Wuxal Super (Supplementary Liquid foliar fertilizer)

(i)	Total Nitrogen (N), percent by weight, minimum	8.000
(ii)	Water soluble phosphates (as P_2O_5) percent by weight, minimum	8.000
(iii)	Water soluble Potassium (as K_2O), percent by weight, minimum	6.000
(iv)	Water soluble Boron (B), percent by weight, minimum	0.010
(v)	Water soluble Copper (Cu)percent by weight, minimum	0.007
(vi)	Water soluble Iron (Fe)percent by weight, minimum	0.015
(vii)	Water soluble Manganese (Mn)percent by weight, minimum	0.013
(viii)	Water soluble Molybdenum (Mo)percent by weight, minimum	0.001
(ix)	Water soluble Zinc (Zn)percent by weight, minimum	0.005
(x)	Colour	Green
(xi)	Density	1.24 (approx)
(xii)	pH	5.4 (approx)
(xiii)	Physical Condition	Liquid
	*as chelate of EDTA	

26. Name of the Product: Zinc Sulphate (Chasi Brand)

(i)	Total Zinc (Zn), percent by weight, minimum	13.00
(ii)	Water soluble Zinc (Zn), content as percent of total Zinc, minimum	97.00
(iii)	Sulphur (S), percent by weight, minimum	6.50
(iv)	Magnesium (Mg), percent by weight, minimum	0.15
(v)	pH	4.00(approx)
(vi)	Physical Condition	Liquid

27. Name of the Product: Micro (Micronutrient fertilizer)

(i)	Total Zinc (Zn), percent by weight, minimum	11.00
(ii)	Water soluble Calcium (Ca) percent by weight, minimum	15.00
(iii)	Water soluble Magnesium (Mg), percent by weight, minimum	2.80
(iv)	Water soluble Sulphur (S), percent by weight, minimum	7.50
(v)	Water soluble Copper (Cu), percent by weight, minimum	0.70
(vi)	Water soluble Iron (Fe), percent by weight, minimum	0.50

(vii)	Water soluble Boron (B), percent by weight, minimum	1.00
(viii)	Colour	Green
(ix)	Physical Condition	Powder

28. Name of the Product: Eild (Plant growth regulator)

(i)	Active ingredient: Triacontanol (water based)	@37.5 mg/1500 ml.
(ii)	Colour	Light green
(iii)	Physical Condition	Liquid

29. Name of the Product: Bioferti (Plant growth regulator)

(i)	Ingredients:	
	(a) Concentrated Liquid 15% humus	97 percent
	(b) 48% Ammonium LaurethSultate	03 percent
(ii)	Colour	Dark brown
(iii)	Physical Condition:	Liquid

30. **Name of the Product: Agnol (Plant growth regulator)**

(i)	Active ingredient: Triacontanol (Xylene based)	@37.5 mg/litre
(ii)	Colour	Colourless
(iii)	Physical Condition	Liquid

31. Name of the Product: Neugol (Narural organic plant nutrient)

(i)	Total Nitrogen, percent by weight, minimum	1.250
(ii)	Water Phosphate (P_2O_5) percent by weight, minimum	0.220
(iii)	Potassium (as K_2O), percent by weight, minimum	1.760
(iv)	Magnesium (MgO), percent by weight, minimum	0.250
(v)	Caelcium (as CaO), percent by weight, minimum	0.400
(vi)	Total sulphur (as S), percent by weight, minimum	0.693
(vii)	Total Zinc (as Zn), percent by weight, minimum	0.213
(viii)	Total Mn (as Mn), percent by weight, minimum	0.0077
(ix)	Total Fe (as Fe), percent by weight, minimum	0.0237
(x)	Total Cu (as Cu), percent by weight minimum	0.051
(xi)	Total Boron (as B), percent by weight, minimum	0.0009
(xii)	Humic acid, percent by weight, minimum	0.737
(xiii)	Colour	Brown
(xiv)	Sp gravity	1.09 (approx)
(xv)	pH	4.1 (approx)
(xvi)	Physical Condition	Solution

32. Name of the Product: Extazinc soil (Micronutrient fertilizer)

(i)	Total Zinc (Zn), percent by weight, minimum	8.000
(ii)	Total Magnesium (Mg), percent by weight, minimum	2.000
(iii)	Calcium (as CaO), percent by weight, minimum	15.000
(iv)	Total Sulphur (S), percent by weight, minimum	5.000
(v)	Total Lead (Pb), percent by weight, minimum	0.001
(vi)	Colour	White to grey
(vii)	pH (1.5)	6.0 (approx)
(viii)	Moisture content, percent by weight, minimum	10.0
(ix)	Solubility in water	Soluble
(x)	Physical Condition	Granular/Crystalline

33. Name of the Product: Estamin soil (Micronutrient fertilizer)

(i)	Total Zinc (Zn), percent by weight, minimum	8.000
(ii)	Total Born (B), percent by weight, minimum	0.500
(iii)	Total Manganese (Mn), percent by weight, minimum	0.250
(iv)	Total Copper (Cu), percent by weight, minimum	0.250
(v)	Total Molybdenum (Mo), percent by weight, minimum	0.019
(vi)	Total Magnesium (Mg), percent by weight, minimum	1.000
(vii)	Calcium (as CaO), percent by weight, minimum	15.000
(viii)	Lead (Pb), percent by weight, minimum	0.001
(ix)	Colour	Grey to cream
(x)	pH (1.5)	7.5 (approx)
(xi)	Moisture content, percent by weight, minimum	10.0
(xii)	Solubility in water, percent by weight, minimum	95.0
(xiii)	Physical Condition	Powder

34. Name of the Product: Estamin Foliar (Micronutrient fertilizer)

(i)	Total Zinc (Zn), percent by weight, minimum	6.30
(ii)	Total Born (B), percent by weight, minimum	2.50
(iii)	Total Manganese (Mn), percent by weight, minimum	5.40
(iv)	Total Copper (Cu), percent by weight, minimum	0.25
(v)	Total Molybdenum (Mo), percent by weight, minimum	0.50
(vi)	Total Iron (Fe), percent by weight, minimum	0.25
(vii)	Total Sulphur (S), percent by weight, minimum	11.2
(viii)	Total Magnesium (Mg), percent by weight, minimum	1.00
(ix)	Potassium (as K_2O), percent by weight, minimum	9.70
(x)	Lead (Pb), percent by weight, minimum	0.001
(xi)	Colour	Grey to cream

(xii)	pH (1.5)	6.50
(xiii)	Moisture, percent by weight, minimum	2.00
(xiv)	Solubility in water, percent by weight, minimum	95.00
(xv)	Physical Condition	Powder

35. <u>Name of the Product: Estamin (Inorganic foliar fertilizer)</u>

(i)	Total Sulphur (S), percent by weight, minimum	20.00
(ii)	Total Calcium (as CaO), percent by weight, minimum	20.00
(iii)	Total Iron (Fe), percent by weight, minimum	0.005
(iv)	Total Lade (Pb), percent by weight, maximum	0.001
(v)	Colour	Clear Brown
(vi)	pH (1.5)	7.0 (approx)
(vii)	Solubility in water, percent by weight, minimum	94.0
(viii)	Physical Condition	Liquid

36. <u>Name: NPKS (12-15-20-6) For Wheat & other Rabicrops</u>

(i)	Total Nitrogen, percent by weight, minimum	12.00
(ii)	Nautral ammonium citrate soluble Phosphates (as P_2O_5), percent by weight, minimum	15.00
(iii)	Water soluble Potash (as K_2O), percent by weight, minimum	20.00
(iv)	Total Sulphur, percent by weight, minimum	6.00
(v)	Water soluble sulphate (as SO_4-S), percent by weight, minimum	5.00
(vi)	Moisture, percent by weight, maximum	(a)Powder 3.0 (b)Granular 2.0
(vii)	Particle size-90 percent of the material pass through 4mm IS sieve and not more than 5 percent pass through 1mm IS sieve.	
(viii)	Physical Condition	Granular/ Powder

37. <u>Name: Natur's gift (Liquid Gold)</u>

(i)	Nitrogen (N)	14.2%
(ii)	Potassium (K)	2.0%
(iii)	Phosphorus (P)	1.1%
(iv)	Sulpher (S)	3000mg/L
(v)	Calcium (Ca)	400mg/L
(vi)	Magnesium (Mg)	400mg/L
(vii)	Zinc (Zn)	145mg/L
(viii	Sodium (Na)	75mg/L

)		
(ix)	Iron (Fe)	4 mg/L
(x)	Boron (B)	2 mg/L
(xi)	Copper (Cu)	1 mg/L
(xii)	Manganese(Mn)	1 mg/L
(xiii)	Molybdenum (Mo)	0.1 mg/L

38. <u>Name of the Product: E-2001 of SNS International</u>

(i)	Ingredient a) Proprietary Blend of immobilized nitrogen-fixing cell such b) Proprietary blend of know enzymes and solutes	
(ii)	Colour	Deep brown
(iii)	Specific gravity	01
(iv)	pH	6.5
(v)	Solubility	Completely soluble in water
(vi)	Flammability	Non-flammable
(vii)	Toxicity	Nil
(viii)	Physical condition	Liquid

39. <u>Name of the Product: Annapurna JaibaSar</u>

(i)	Total Nitrogen(N), percent by weight, minimum	0.91
(ii)	Total Phosphate (P), percent by weight, minimum	0.4
(iii)	Total Potassium (K), percent by weight, minimum	1.50
(iv)	Total Sulphur (S), percent by weight, minimum	0.52
(v)	Total Zinc (Zn), percent by weight, minimum	0.02
(vi)	Total Boron (B), percent by weight, minimum	0.06
(vii)	Total Copper (Cu), percent by weight, minimum	0.02
(viii)	Total Manganese (Mn), percent by weight, minimum	0.03
(ix)	Organic Matter (O.M), percent by weight, minimum	7.13
(x)	Colour	Light to dark brown
(xi)	Moisture, percent by weight, maximum	22.00
(xii)	Physical Condition	Powder/Coarse Organic material

40. <u>Name of the Product: Northern BF (HYV Rice)</u>

(i)	Total Nitrogen (N), percent by weight, minimum	6.48
(ii)	Phosphate (P), percent by weight, minimum	4.56
(iii)	Potassium (K), percent by weight, minimum	12.0

(iv)	Sulphur (S), percent by weight, minimum	3.36
(v)	Zinc (Zn), percent by weight, minimum	0.40
(vi)	Boron (B), percent by weight, minimum	0.10
(vii)	Organic Material (O.M), percent by weight, minimum	23.00
(viii)	Colour	Greyish brown
(ix)	Moisture, percent by weight, maximum	4.23
(x)	Physical Condition	Powder/Coarse Organic material

41.<u>Name of the Product: Northern BF (Wheat)</u>

(i)	Total Nitrogen (N), percent by weight, minimum	5.56
(ii)	Phosphorus (P), percent by weight, minimum	4.98
(iii)	Potassium (K), percent by weight, minimum	11.5
(iv)	Sulphur (S), percent by weight, minimum	4.08
(v)	Zinc (Zn), percent by weight, minimum	0.20
(vi)	Boron (B), percent by weight, minimum	0.10
(vii)	Organic material, percent by weight, minimum	21.00
(viii)	Colour	Grayish brown
(ix)	Moisture, percent by weight, minimum	5.83
(x)	Physical Condition	Powder/Coarse Organic material

42.<u>Name of the Product: Northern BF (Potato)</u>

(i)	Total Nitrogen (N), percent by weight, minimum	6.22
(ii)	Phosphorus (P), percent by weight, minimum	3.0
(iii)	Potassium (K), percent by weight, minimum	11.5
(iv)	Sulphur (S), percent by weight, minimum	0.04
(v)	Zinc (Zn), percent by weight, minimum	2.40
(vi)	Boron (B), percent by weight, minimum	0.10
(vii)	Organic material, percent by weight, minimum	34.00
(viii)	Colour	Greyish brown
(ix)	Moisture, percent by weight, minimum	6.00
(x)	Physical Condition	Powder/Coarse Organic material

43.<u>Name of the Product: Northern BF (Mustard)</u>

(i)	Total Nitrogen (N), percent by weight, minimum	7.25
(ii)	Phosphorus (P), percent by weight, minimum	4.00
(iii)	Potassium (K), percent by weight, minimum	7.00
(iv)	Sulphur (S), percent by weight, minimum	3.96
(v)	Zinc (Zn), percent by weight, minimum	0.40
(vi)	Boron (B), percent by weight, minimum	0.10
(vii)	Organic material, percent by weight, minimum	33.00
(viii)	Colour	Greyish brown
(ix)	Moisture, percent by weight, minimum	6.20
(x)	Physical Condition	Powder/CoarseOrga

nic material

44.<u>Name of the Product: Northern BF (Maize)</u>

(i)	Total Nitrogen (N), percent by weight, minimum	6.82
(ii)	Phosphorus (P), percent by weight, minimum	4.00
(iii)	Potassium (K), percent by weight, minimum	9.50
(iv)	Sulphur (S), percent by weight, minimum	3.60
(v)	Zinc (Zn), percent by weight, minimum	0.20
(vi)	Boron (B), percent by weight, minimum	0.10
(vii)	Organic material, percent by weight, minimum	32.00
(viii)	Colour	Greyish brown
(ix)	Moisture, percent by weight, maximum	6.48
(x)	Physical Condition	Powder/Coarse Organic material

45.<u>Name of the Product: Northern BF (Banana)</u>

(i)	Total Nitrogen (N), percent by weight, minimum	2.88
(ii)	Phosphorus (P), percent by weight, minimum	5.66
(iii)	Potassium (K), percent by weight, minimum	11.00
(iv)	Sulphur (S), percent by weight, minimum	4.20
(v)	Zinc (Zn), percent by weight, minimum	0.10
(vi)	Boron (B), percent by weight, minimum	0.10
(vii)	Organic material, percent by weight, minimum	26.00
(viii)	Colour	Greyish brown
(ix)	Moisture, percent by weight, maximum	5.10
(x)	Physical Condition	Powder/Coarse Organic material

46.<u>Name of the Product: Northern BF (Onion)</u>

(i)	Total Nitrogen (N), percent by weight, minimum	5.00
(ii)	Phosphorus (P), percent by weight, minimum	5.38
(iii)	Potassium (K), percent by weight, minimum	12.50
(iv)	Sulphur (S), percent by weight, minimum	4.08
(v)	Organic material, percent by weight, minimum	21.00
(vi)	Colour	Greyish brown
(vii)	Moisture, percent by weight, maximum	3.25
(viii)	Physical Condition	Powder/Coarse Organic material

47.<u>Name of the Product: Northern BF (Chilli)</u>

(i)	Total Nitrogen (N), percent by weight, minimum	4.78

(ii)	Phosphorus (P), percent by weight, minimum	6.00
(iii)	Potassium (K), percent by weight, minimum	9.50
(iv)	Sulphur (S), percent by weight, minimum	2.04
(v)	Zinc (Zn), percent by weight, minimum	0.20
(vi)	Boron (B), percent by weight, minimum	0.10
(vii)	Organic material, percent by weight, minimum	38.00
(viii)	Colour	Grayish brown
(ix)	Moisture, percent by weight, maximum	5.73
(x)	Physical Condition	Powder/Coarse Organic material

48.Name of the Product: Northern BF (Sugarcane)

(i)	Total Nitrogen (N), percent by weight, minimum	5.54
(ii)	Phosphorus (P), percent by weight, minimum	5.84
(iii)	Potassium (K), percent by weight, minimum	7.50
(iv)	Sulphur (S), percent by weight, minimum	3.42
(v)	Zinc (Zn), percent by weight, minimum	0.10
(vi)	Boron (B), percent by weight, minimum	0.10
(vii)	Organic material, percent by weight, minimum	28.00
(viii)	Colour	Grayish brown
(ix)	Moisture, percent by weight, maximum	5.48
(x)	Physical Condition	Powder/Coarse Organic material

49.Name of the Product: Northern BF (Watermelon)

(i)	Total Nitrogen (N), percent by weight, minimum	5.26
(ii)	Phosphorus (P), percent by weight, minimum	3.80
(iii)	Potassium (K), percent by weight, minimum	9.00
(iv)	Sulphur (S), percent by weight, minimum	3.42
(v)	Zinc (Zn), percent by weight, minimum	0.10
(vi)	Boron (B), percent by weight, minimum	0.10
(vii)	Organic material, percent by weight, minimum	38.00
(viii)	Colour	Grayish brown
(ix)	Moisture, percent by weight, maximum	8.90
(x)	Physical Condition	Powder/Coarse Organic material

50.Name of the Product: Northern BF (Cauliflower)

(i)	Total Nitrogen (N), percent by weight, minimum	3.42
(ii)	Phosphorus (P), percent by weight, minimum	3.80
(iii)	Potassium (K), percent by weight, minimum	4.00
(iv)	Sulphur (S), percent by weight, minimum	2.34
(v)	Zinc (Zn), percent by weight, minimum	0.12

(vi)	Boron (B), percent by weight, minimum	1.41
(vii)	Organic material, percent by weight, minimum	44.00
(viii)	Colour	Greyish brown
(ix)	Moisture, percent by weight, maximum	9.15
(x)	Physical Condition	Powder/Coarse Organic material

51.<u>Name of the Product: Northern BF (Cabbage)</u>

(i)	Total Nitrogen (N), percent by weight, minimum	2.88
(ii)	Phosphorus (P), percent by weight, minimum	3.20
(iii)	Potassium (K), percent by weight, minimum	5.50
(iv)	Sulphur (S), percent by weight, minimum	3.06
(v)	Boron (B), percent by weight, minimum	0.10
(vi)	Organic material, percent by weight, minimum	55.00
(vii)	Colour	Greyish brown
(viii)	Moisture, percent by weight, maximum	6.78
(ix)	Physical Condition	Powder/Coarse Organic material

52.<u>Name of the Product: Northern BF (Brinjal)</u>

(i)	Total Nitrogen (N), percent by weight, minimum	8.20
(ii)	Phosphorus (P), percent by weight, minimum	4.00
(iii)	Potassium (K), percent by weight, minimum	7.00
(iv)	Sulphur (S), percent by weight, minimum	1.44
(v)	Organic material, percent by weight, minimum	55.00
(vi)	Colour	Greyish brown
(vii)	Moisture, percent by weight, maximum	6.63
(viii)	Physical Condition	Powder/Coarse Organic material

53.<u>Name of the Product: Northern BF (Tomato)</u>

(i)	Total Nitrogen (N), percent by weight, minimum	3.42
(ii)	Phosphorus (P), percent by weight, minimum	3.80
(iii)	Potassium (K), percent by weight, minimum	5.50
(iv)	Sulphur (S), percent by weight, minimum	2.88
(v)	Boron (B), percent by weight, minimum	0.02
(vi)	Organic material, percent by weight, minimum	52.00
(vii)	Colour	Greyish brown
(viii)	Moisture, percent by weight, maximum	6.53
(ix)	Physical Condition	Powder/Coarse

Organic material

54.Name of the Product: Northern BF (Garlic)

(i)	Total Nitrogen (N), percent by weight, minimum	6.00
(ii)	Phosphorus (P), percent by weight, minimum	5.08
(iii)	Potassium (K), percent by weight, minimum	14.50
(iv)	Sulphur (S), percent by weight, minimum	2.52
(v)	Organic material, percent by weight, minimum	26.00
(vi)	Colour	Greyish brown
(vii)	Moisture, percent by weight, maximum	4.53
(viii)	Physical Condition	Powder/Coarse Organic material

55.Name of the Product: Northern BF SaktiSar

(i)	Total Nitrogen (N), percent by weight, minimum	6.00
(ii)	Phosphorus (P), percent by weight, minimum	3.50
(iii)	Potassium (K), percent by weight, minimum	8.50
(iv)	Sulphur (S), percent by weight, minimum	2.00
(v)	Boron (B), percent by weight, minimum	0.10
(vi)	Calcium (Ca), percent by weight, minimum	2.00
(vii)	Magnesium (Mg), percent by weight, minimum	1.00
(viii)	Colour	Greyish brown
(ix)	Moisture, percent by weight, maximum	6.23
(x)	Physical Condition	Powder/Coarse Organic material

56.Name of the Product: Microsoil

(i)	Ingredients (a) Proprietary blend of known and non-pathogentic soil microorganisms such as Azotobacter and Clostridium (b) Proprietary blend of organic minerals, vitamins and natural polysaccharide and polypeptones	
(ii)	Colour	Deep brown
(iii)	Specific gravity	1.0
(iv)	pH	5.0-7.0
(v)	Solubility	Fully soluble in water
(vi)	Flammability	Non-flammable
(vii)	Physical condition	Liquid

57.Nutraphos N

(i)	Total Nitrogen (N), percent by weight, minimum	16.0
(ii)	Available Phosphate (O_2O_5), percent by weight, minimum	12.0
(iii)	Calcium (Ca), percent by weight, minimum	4.0

(iv)	Magnesium (Mg), percent by weight, minimum	1.5
(v)	Zinc (Zn), percent by weight, minimum	2.0
(vi)	Boron (B), percent by weight, minimum	1.0
(vii)	Iron (Fe), percent by weight, minimum	1.0
(viii)	Colour	Off-white
(ix)	pH	7.0-9.0
(x)	Moisture, percent by weight, maximum	2.0
(xi)	Physical Condition	Powder (Fine Powder)

58.<u>Nutraphos-24</u>

(i)	Available Phosphate (O_2O_5), percent by weight, minimum	24.0
(ii)	Calcium (Ca), percent by weight, minimum	20.0
(iii)	Sulphur (S), percent by weight, minimum	6.0
(iv)	Zinc (Zn), percent by weight, minimum	12.0
(v)	Colour	White
(vi)	pH	6.9-9.0
(vii)	Moisture, percent by weight, maximum	7
(viii)	Physical Condition	Powder(Fine Powder)

59.<u>Nutraphos Super K</u>

(i)	Total Nitrogen (N), percent by weight, minimum	7.0
(ii)	Available Phosphate (O_2O_5), percent by weight, minimum	13.0
(iii)	Soluble Potash (K_20), percent by weight, minimum	34.0
(iv)	Zinc (Zn), percent by weight, minimum	12.0
(v)	Colour	Off-white
(vi)	pH	7.0-10.0
(vii)	Moisture, percent by weight, maximum	7.0
(viii)	Physical Condition	Powder (Fine Powder)

60.<u>Sulphur-95</u>

(i)	TotalSulphur, percent by weight, minimum	95.0
(ii)	Moisture, percent by weight, minimum	0.5
(iii)	Physical Condition	Granular

61.<u>BINAZibanuSar (Bio-Fertilizer)</u>

(i) Name of Organisms: Bacterial (Rhizobia and Bradyrhizobia) strains

(ii) Order: Eubacterials

(iii) Family: Rhizobicaceac

(iv)

	Host	Single/mixed culture	Bacteria
1) Lentil (Musure)	Lens culinaris	Mixed	Rhizobium
2) Chickpea (Sola)	Cleerarietinum	Mixed	Bradyrhizobium

3) Groundnut (Chinabadam)	Arachishypogaca	Mixed	Bradyrhizobium
4) Mungbean (Mung)	Vigna radiate	Mixed	Bradyrhizobium
5) Mashcoli (Mash)	Vignammgo	Mixed	Bradyrhizobium
6) Cowpea (Barboti)	Vignaunguiculata	Mixed	Bradyrhizobium
7) Soybean	Glycine max	Mixed	Bradyrhizobium

62.Dolomite Lime [$CaMg(CO_3)_2$]

(i)	Acidity neutralizing power (Ca CO3) equivalent 100)	109
(ii)	Total Calcium (Ca), percent by weight, minimum	20.00
(iii)	Total Magnesium (Mg), percent by weight, minimum	11.00
(iv)	Total Iron (Fe), percent by weight, minimum	0.13
(v)	Total Silicon (Si), percent by weight, maximum	0.75
(vi)	Colour	Off white
(vii)	pH	8.5
(viii)	Particle Size	80.100 mesh
(ix)	Specific gravity	1.4
(x)	Moisture Content, percent by weight, maximum	3.0
(xi)	Physical Condition	Powder

63.Calcitic Lime: Agricultural ($CaCO_3$)

(i)	Acidity neutralizing power	100
(ii)	Total Calcium (Ca), percent by weight, minimum	34.0
(iii)	Total Magnesium (Mg), percent by weight, minimum	0.15
(iv)	Total Iron (Fe), percent by weight, minimum	0.15
(v)	Total Silicon (Si), percent by weight, maximum	2.0
(vi)	Colour	white
(vii)	pH	9.00
(viii)	Particle Size	100.120 mesh
(ix)	Specific gravity	1.4
(x)	Moisture Content, percent by weight, maximum	3.0
(xi)	Physical Condition	Powder

64.Chook Chook-150

(i)	Total Nitrogen (N), percent by weight, minimum	4.50
(ii)	Phosphorus (P), percent by weight, minimum	4.50
(iii)	Potassium (K), percent by weight, minimum	6.03

(iv)	Sulphur (S), percent by weight, minimum	1.72
(v)	Zinc (Zn), percent by weight, minimum	1.50
(vi)	Boron (B), percent by weight, minimum	0.09
(vii)	Calcium (Ca), percent by weight, minimum	10.00
(viii)	Magnesium (Mg), percent by weight, minimum	1.30
(ix)	Manganese (Mn), percent by weight, minimum	1.18
(x)	Copper (Cu), percent by weight, minimum	0.006
(xi)	Organic matter, percent by weight, minimum	23.62
(xii)	Colour	Brownish
(xiii)	pH	7.00(approx)
(xiv)	Moisture, percent by weight, maximum	10.00
(xv)	Physical Condition	Powder(Coarse /Fibrous)

65.Chook Chook-102

(i)	Total Nitrogen (N), percent by weight, minimum	2.80
(ii)	Phosphorus (P), percent by weight, minimum	3.72
(iii)	Potassium (K), percent by weight, minimum	3.11
(iv)	Sulphur (S), percent by weight, minimum	0.51
(v)	Zinc (Zn), percent by weight, minimum	0.45
(vi)	Boron (B), percent by weight, minimum	0.15
(vii)	Calcium (Ca), percent by weight, minimum	12.00
(viii)	Magnesium (Mg), percent by weight, minimum	0.67
(ix)	Manganese (Mn), percent by weight, minimum	0.07
(x)	Copper (Cu), percent by weight, minimum	0.01
(xi)	Iron (Fe), percent by weight, minimum	0.87
(xii)	Organic matter, percent by weight, minimum	25.36
(xiii)	Colour	Brownish
(xiv)	pH	7.00(approx)
(xv)	Moisture, percent by weight, maximum	10.00
(xvi)	Physical Condition	Powder (Coarse/Fibrous)

66.Silvagen

(i)	Total Nitrogen (N), percent by weight, minimum	24.00
(ii)	Total Phosphorus (P), percent by weight, minimum	2.2
(iii)	Water Soluble Phosphoros (P), percent by weight, minimum	1.1
(iv)	Total Potassium (K), percent by weight, minimum	8.3
(v)	Water Soluble Potassium (K), percent by weight, minimum	7.9
(vi)	Total Magnesium (Mg), percent by weight, minimum	2.1
(vii)	Sulphur (S), percent by weight, minimum	3.0
(viii)	Cadmium (Cd), percent by weight, maximum	0.002
(ix)	Lead (Pb), percent by weight, maximum	0.0015
(x)	Mercury (Hg), percent by weight, maximum	0.0005
(xi)	Arsenic (As), percent by weight, maximum	0.001

(xii)	Chromium (Cr), percent by weight, maximum	0.100
(xiii)	Colour	Gray
(xiv)	Solubility in Water	Partially soluble
(xv)	pH (1:2.5)	7.1(approx)
(xvi)	Moisture, percent by weight, minimum	3.00
(xvii)	Physical Condition	Powder (Coarse/Fibrous)

67.<u>Silvamix</u>

(i)	Total Nitrogen (N), percent by weight, minimum	11.000
(ii)	Total Phosphorus (P), percent by weight, minimum	7.480
(iii)	Water Soluble Phosphoros (P), percent by weight, minimum	2.640
(iv)	Total Potassium (K), percent by weight, minimum	6.640
(v)	Water Soluble Potassium (K), percent by weight, minimum	4.980
(vi)	Total Magnesium (Mg), percent by weight, minimum	4.200
(vii)	Sulphur (S), percent by weight, minimum	1.500
(viii)	Cadmium (Cd), percent by weight, maximum	0.002
(ix)	Lead (Pb), percent by weight, maximum	0.005
(x)	Mercury (Hg), percent by weight, maximum	0.0015
(xi)	Arsenic (As), percent by weight, maximum	0.001
(xii)	Chromium (Cr), percent by weight, maximum	0.100
(xiii)	Colour	Gray
(xiv)	Solubility in Water	Partially soluble
(xv)	pH (1:2.5)	7.3(approx)
(xvi)	Moisture, percent by weight, minimum	3.0
(xvii)	Physical Condition	Solid(Tablet from)

68.<u>Silvamix-Forte</u>

(i)	Total Nitrogen (N), percent by weight, minimum	17.500
(ii)	Total Phosphorus (P), percent by weight, minimum	7.700
(iii)	Water Soluble Phosphoros (P), percent by weight, minimum	3.080
(iv)	Total Potassium (K), percent by weight, minimum	8.710
(v)	Water Soluble Potassium (K), percent by weight, minimum	7.050
(vi)	Total Magnesium (Mg), percent by weight, minimum	5.400
(vii)	Sulphur (S), percent by weight, minimum	0.300
(viii)	Cadmium (Cd), percent by weight, maximum	0.002
(ix)	Lead (Pb), percent by weight, maximum	0.0015
(x)	Mercury (Hg), percent by weight, maximum	0.0005
(xi)	Arsenic (As), percent by weight, maximum	0.001
(xii)	Chromium (Cr), percent by weight, maximum	0.100
(xiii)	Colour	Gray

(xiv)	Solubility in Water	Partially soluble
(xv)	pH (1:2.5)	7.3(approx)
(xvi)	Moisture, percent by weight, minimum	3.0
(xvii)	Physical Condition	Solid(Tablet from)

69.<u>Fused Magnesium Phosphate (BÿzPv‡le¨env‡iiRb¨)</u>

(i)	Phosphorus (P), percent by weight, minimum	7.92
(ii)	Calcium (Ca), percent by weight, minimum	23.43
(iii)	Magnesium (Mg), percent by weight, minimum	7.30
(iv)	Silicon (Si), percent by weight, minimum	9.40
(v)	Colour	Greyish/brown
(vi)	pH (1:2.5)	8.5-8.9
(vii)	Moisture, percent by weight, maximum	1.50
(viii)	Physical Condition	Powder

70.<u>Name of the Product: Feovit-55</u>

(i)	Total Nitrogen (N), percent by weight, minimum	5.000
(ii)	Total Phosphorus (P), percent by weight, minimum	6.000
(iii)	Total Potassium (K), percent by weight, minimum	7.000
(iv)	Total Sulphur (S), percent by weight, minimum	5.000
(v)	Total Zinc (Zn), percent by weight, minimum	0.020
(vi)	Water Soluble Boron (B), percent by weight, minimum	0.001
(vii)	Calcium (Ca), percent by weight, minimum	10.000
(viii)	Magnesium (Mg), percent by weight, minimum	5.000
(ix)	Arsenic (As), percent by weight, maximum	10.000
(x)	Cadmium (Cd), percent by weight, maximum	9.000
(xi)	Lead (Pb), percent by weight, maximum	5.000
(xii)	Organic matter, percent by weight, maximum	
(xiii)	Colour	Gray
(xiv)	pH	6.0-7.0
(xv)	Moisture, percent by weight, maximum	16.00
(xvi)	Physical Condition	Granular
(xvii)	Solubility in Water	Partially soluble
(xviii)	Particle size	80 percent of the material shall pass through 4-2mm IS sieve

73.<u>Name of the Product:Keumjatop</u>

(i)	Total Nitrogen (N), percent by weight, minimum	5.00
(ii)	Total Phosphorus (P), percent by weight, minimum	2.20

(iii)	Total Potassium (K), percent by weight, minimum	2.50
(iv)	Total Zinc (Zn), percent by weight, minimum	0.05
(v)	Boron (B), percent by weight, minimum	0.01
(vi)	Magnesium (Mg), percent by weight, minimum	0.60
(vii)	Manganese (Mn), percent by weight, minimum	0.077
(viii)	Copper (Cu), percent by weight, minimum	0.05
(ix)	Iron (Fe), percent by weight, minimum	0.10
(x)	Colour	Brown
(xi)	pH	2.3-2.5
(xii)	Physical Condition	Liquid
(xiii)	Solubility in Water	Miscible
(xiv)	Specific gravity (20^0C)	1.20-1.25

74.<u>Name of the Product: Chook-Chook (Tomato) (Organo-chemical fertilizer)</u>

(i)	Organic Matter, percent by weight, minimum	17.970
(ii)	Total Nitrogen (N), percent by weight, minimum	3.830
(iii)	Total Phosphorus (P), percent by weight, minimum	2.280
(iv)	Total Potassium (K), percent by weight, minimum	4.500
(v)	Total Sulphur (S), percent by weight, minimum	1.240
(vi)	Calcium (Ca), percent by weight, minimum	2.800
(vii)	Magnesium (Mg), percent by weight, minimum	1.420
(viii)	Total Zinc (Zn), percent by weight, minimum	0.316
(ix)	Total Boron (B), percent by weight, minimum	0.030
(x)	Manganese (Mn), percent by weight, minimum	0.090
(xi)	Copper (Cu), percent by weight, minimum	0.005
(xii)	Iron (Fe), percent by weight, minimum	0.540
(xiii)	Cadmium (Cd), percent by weight, maximum	0.00089
(xiv)	Lead (Pd), percent by weight, maximum	0.00029
(xv)	Arsenic (As), percent by weight, maximum	0.0004
(xvi)	Colour	Grey
(xvii)	pH	7.10
(xviii)	Moisture, percent by weight, maximum	10
(xix)	Physical Condition	Powder
(xx)	Solubility % in Water (fertilizer to water = 1:10)	Partially soluble

75.<u>Name of the Product: Aquasorb™3005^{KM}</u>

(i)	Physical Condition	Free flowing powder
(ii)	Colour	White
(iii)	Moisture, percent by weight, maximum	0-13%
(iv)	pH	Neutral
(v)	Solubility	Not Applicable (100% Biodegradable)

76.<u>Name of the Product: Flobond™</u>

(i)	Physical Condition	Free flowing powder
(ii)	Colour	White
(iii)	Moisture, percent by weight, maximum	0-15%
(iv)	pH	Neutral
(v)	Solubility	Not Applicable (100% Biodegradable)

77.<u>Name of the Product: Chook-Chook (Banana)</u>

(i)	Physical Condition	Fibrous powder
(ii)	Colour	Brown
(iii)	Moisture (%)	6.50
(iv)	OM (%)	21.76
(v)	Ca(%)	8.00
(vi)	Mg (%)	1.13
(vii)	K_2O (%)	5.36
(viii)	TN (%)	3.33
(ix)	P_2O_5 (%)	9.15
(x)	S (%)	2.83
(xi)	B (%)	0.03
(xii)	Cu (%)	0.005
(xiii)	Zn (%)	1.50
(xiv)	Mn(%)	0.15

78.<u>Northern organic fertilizer for tea</u>

(i)	Physical Condition	Powder
(ii)	Colour	Grayish Black
(iii)	Moisture (%)	10%
(iv)	N	4%
(v)	P_2O_5	1.15%
(vi)	K_2O	1.5%
(vii)	S	1.0%
(viii)	Ca	2.5%
(ix)	Mg	0.75%
(x)	Fe	0.05%
(xi)	Mn	170 ppm
(xii)	Zn	150 ppm
(xiii)	Cu	24 ppm
(xiv)	B	1.60 ppm
(xvi)	Mo	3.0 ppm
(xvii)	OM	10.0%

(Source : Ministry of Agriculture (MoA), Bangladesh)