THESIS REPORT

National Institute of Technology Rourkela

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SINGLE STAGE ANAEROBIC DIGESTION FOR SEWAGE SLUDGE TREATMENT

A Thesis submitted in partial fulfilment

for the requirement of the degree of

Bachelor of Technology in Civil Engineering

By

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Certificate of Approval

This is to certify that the thesis entitled ***'*SINGLE STAGE ANAEROBIC DIGESTION FOR SEWAGE SLUDGE TREATMENT*'*** submitted by **Anubhav Abhinav** (111CE0026) has been carried out under my supervision in partial fulfillment of the requirements for the Degree of Bachelor of Technology in Department of Civil Engineering at National Institute of Technology Rourkela, and this work has not been submitted elsewhere before for any other academic degree/diploma.

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ABSTRACT

National Institute of Technology Rourkela is one of the largest academic institutions in India with lots of people residing in its campus. Such large number of people will lead to large amount of sewage from hostels and academic areas. A sewage treatment plant has setup near V.S. Hall of Residence for the treatment of all municipal wastes from the hostels and academic areas. As a result a considerable amount of municipal sewage sludge is generated in the plant which has no use.

Chemical characterization has been performed on the municipal sewage sludge so that it can be used as a domestic fertilizer. The present study involves the analysis of heavy metals such as mercury, arsenic, iron, nickel, copper, zinc, calcium, lead, chromium, magnesium, aluminum, sodium, potassium, phosphorus, silicon by using the Atomic Absorption Spectrometer. The physical and chemical parameters like TOC, hardness, colour, pH, total nitrogen, fluoride has also been determined for the sewage sludge sample.

Six number of samples are collected from the Sewage Treatment Plant at different times of the day to have an average data of the measured parameters. The average values of all the parameters are found out. The samplings are also dried in different methods to have a comparative study.

Keywords: characterization, sewage, municipal waste

INTRODUCTION

INTRODUCTION

1.1 SLUDGE

The solid byproducts left out after the purification and filtration process of waste water is called sludge. Sludge is composed of pollutants that have been removed by sedimentation and filtration. It comprises of solid waste, heavy metals, pathogens and disease causing organisms. Since sludge is a biodegradable element and is rich in organic content it has various uses in the field of environmental engineering.

Sludge is the end product of the waste water treatment process. There are many physical and chemical processes involved in the treatment process which results in the concentration of heavy metals and many pathogens present in the waste water. But sludge contains valuable nutrients like phosphorus and nitrogen and also abundant organic matter that is very useful when the soil is subjected to erosion. The nutrients and organic matter are the two main reasons why sludge being a waste is used as a fertilizer on lands.

Advantages of using sludge

- **Land filling**: It is the simplest solution for the dumping of sewage sludge. It prevents the spreading of pathogens/pollutants by concentrating the sludge into a single location.
- **Incineration**: In this method sludge is dried and then burned to recover the energy from the sludge. Heat from sludge incineration can also be used for heating buildings. Heat produced can also be used to produce steam and electricity generation. This method destroys pathogens and decomposes organic chemicals.
- **Biofuels production**: municipal sewage sludge can be used for production of methane gas which is rich in energy. It is produced by anaerobic digestion in sludge digesters. Methane gas is used to generate power via turbines. The gas can also be used for household utilization instead of conventional CNG gas.
- **Mine reclamation/landscaping/forestry:** Extensive heat dried sewage sludge can be used on landscapes where organic matter has been depleted through continuous irrigation and cropping/ mining. Here sewage sludge are put in layer in places where soil has no organic value. This result in the increase in the organic content in soil resulting in increase in vegetation cover.
- **Use in Agriculture:** In many developed countries this process has been used for obtaining the nutrients from sludge for plant growth. Sludge is a valuable source of organic matter and are nutrient rich fertilizers. It can contain even more nutrients present in inorganic fertilizers.
- **Other Potential uses include:** Use in cement production, as herbicides, as fish food and also production of bricks.

1.2 Sludge Stabilization

For uses in the above processes sludge has to be properly stabilized and must be free from the toxic organics, heavy metals and disease causing pathogens. It is needed to reduce the harmful content of the sludge so that it can be used in above said processes. Stabilization helps in reducing pathogens, eliminating odors and inhibit the potential for putrefaction. Sludge stabilization is done in following processes.

- **Alkaline stabilization:** In this method alkaline materials are used to make the sludge unsuitable for survival of pathogens. A commonly used alkaline material is lime.it increase the pH value to 12 or more. The high pH environment doesn't destroy the microorganisms but inhibit their growth.
- **Anaerobic Digestion:** In this method the organic matter is converted into methane and carbon dioxide by the process of fermentation. Fermentation occurs in the absence of oxygen. Methane gas can be used for the generation of heat and electricity. The left out bio solids may be suitable for land application. This process can be done in single stage or in two stages.
- **Aerobic Digestion:** this process is similar to anaerobic digestion but with the presence of oxygen. Here no usable gas is produced instead this process is energy intensive. As the supply of available substrate is depleted the microorganisms try to eat themselves which lead to their removal.
- **Auto thermal Thermophilic Digestion:** This process of digestion is equivalent to the aerobic digestion except that huge amount of oxygen is processed to increase the conversion of organic substances present in sludge. This method is operated at a temperature of 40^0C – 80^0C auto thermally in an insulated tank. There are many advantages of this method like degradation of the mass of sludge, inactivation of pathogens and short retention time of sludge.
- **Composting:** It is the process of biological conversion of solid organic matter in an enclosed reactor or in piles. Composting requires addition of a bulking agent to provide an environment suitable for biological activity. Volume of compost is always more than the volume of sludge being composted. This process is very odorous.

In this project work single stage anaerobic digestion has been performed to get the desired stabilization so that characterization of the sample could be performed.

Sewage Treatment Plant is a facility designed to receive the waste from domestic, commercial and industrial sources and to remove materials that damage water quality and compromise public health and safety when discharged into water systems. It includes physical, chemical, and biological processes to remove various contaminants depending on its constituents.

1.3 Objectives of the Study

The principal objective of the study is to use the unused sludge generated from the sewage treatment plant as a domestic fertilizer. The sludge includes household waste solids from toilets, baths, showers, kitchens, sinks and so forth that is disposed of via sewers. Sludge contains a lot of organic matter which if stabilized can be used as manuring agent which can restore the fertility of the soil.

The objectives of the study are:

1. Physical and chemical characterization of the sewage sludge from the Sewage Treatment Plant behind V.S. Hall of Residence, NIT Rourkela.

2. Comparison of the N: P: K ratio of the municipal sludge samples with other synthetic fertilizers and bio solids.

1.4 Literature Review

There is always sludge to be disposed of after the waste water treatment. Secondary sludge treatment plants generate a primary sludge which is generated in the primary filtration/sedimentation process and a secondary sludge after the final filtration/sedimentation process. At the time of disposing the secondary sludge is mixed with primary sludge. The treatment and disposal of sewage sludge cost around half of the original cost. Use of sewage sludge in land applications can reduce significantly the cost as well as the volume of the sludge to be disposed of. Also the plant can get necessary nutrients like potassium and nitrogen from the application of sewage sludge. [1]

In addition to the municipal waste industrial effluents, water from excess rainfall are all transported to the sewage treatment plant via the sewers. Thus the sewage sludge contains many toxic materials with the organic materials. Some of those toxic substances can be harmful to the human/animals so therefore it is necessary to remove or at least control the concentrations of the toxic materials before their application to the soil. [1]

Sewage sludge also contain many pathogenic viruses and bacteria which can provide a potential health hazard to the animals, animals or humans whichever tries to be in contact with it. The pathogenic content in the sewage sludge can be significantly decreased by the application of sewage sludge treatment before it is used in any land application. The risk is further reduced by factors like climate, and time which have a very positive effect on the reduction or control of the pathogenic bacterias. [1]

[2] studied that electrochemical technique is an effective technology that has been applied widely in the wastewater treatment field for its effective degradation of the refractory pollutants. Electro-oxidation of pollutants can take place directly on anodes by generating physically adsorbed active oxygen. The introduction of chloride as supporting mediators for electrolysis will generate some active chlorine species (Cl_2, HClO, and ClO), and these powerful oxidants could efficiently convert high biopolymer substances to low-molecular weight products in the region close to the anode surface.

If the mobilization of the anaerobic microorganisms is prevented in the fixed bed digesters, then it is a very good alternative to reduce the hydraulic retention time of the anaerobic digestion. It can be done so that the hydraulic retention time of the conventional method is very lengthy. 70-80 % of the volatile solids have been removed by the process studied by [3]. By using a fixed bed reactor the hydraulic retention time was reduced from 20 days in a conventional reactor into 3-7 days.

Hygienization treatment method was adopted by [4] for better production of sludge yields to fulfill the legislation of American and European nations for the use of land application. Hygienization treatment is performed after a mesophilic or an anaerobic digestion in a constant temperature of 60 ^{0}C to 80 ^{0}C.

Effect of Co-digestion of sewage sludge with various biodegradable wastes

Various types of enzymes has been used to speed up the process of anaerobic digestion. This has been studied by [5]. The enzymes application can improve the anaerobic degradation of lipids, since it catalyzes the hydrolysis of long chain fatty acids. Enzymes are biodegradable and harmless for the anaerobic treatment processes and aquatic ecosystems; in addition, their contribution to the BOD in the waste stream is negligible. Lipases have been used in anaerobic treatment of fat-wastewater. However, there is a lack of literature regarding the enzyme lipase application in anaerobic co-degradation of solid-lipid waste.

[6] studied that the suitability of mechanically biologically treated material for the anaerobic digestion treatment and the effect of these waste products when co digested with sewage sludge. The results suggested that mechanically biologically treated materials are amenable to anaerobic digestion with sewage sludge. The material contamination of the mechanically biologically treated materials provide a major setback in the recycling of MBT materials as well as in co-digestion.

Anaerobic co-digestion of fruit and vegetable waste and activated sludge was studied by [7] using anaerobic sequencing batch reactors. The effects of activated sludge: fruit vegetable waste ratio and the organic loading rate on digesters performances were examined. Increasing the fruit and vegetable waste proportions in the digestion process significantly increased the biogas production yield.

A great number of experiments have been performed on the co-digestion techniques of sewage sludge with various biodegradable wastes. Some are co-digestion with agro-industrial waste [8], co-digestion with meat processing by products [9], co-digestion with shredded grass [10], co-digestion with rice straw [11] and various other biodegradable waste products. The co digestion process of sludge with different biodegradable wastes and enzymes increases the efficiency of the sludge, increase the volume of sludge produced and also increase in production of methane and hydrogen gas.

MONITORING PROTOCOLS

2.1 Study Area

National Institute of Technology Rourkela is one of the largest academic institutions in India with lots of people residing in its campus. Such large number of people will lead to large amount of sewage from hostels and academic areas. A sewage treatment plant having a capacity of 0.18 MLD has been setup near V.S. Hall of Residence for the treatment of all municipal wastes from the hostels and academic areas. As a result a considerable amount of municipal sewage sludge is generated in the plant which has no use.

The sludge used for the research work is primarily obtained from the Sewage Treatment Plant of capacity 0.18 MLD behind V.S. Hall of Residence and the chemical characterization is done in the environmental engineering lab.

2.2 Sampling Techniques

Six sewage sludge samples have been collected in contamination free sampling bottles of 1000ml. Samples were collected at different times (8 a.m., 12 p.m., and 2 p.m.) and also with different consistencies. Two sampling bottles are then kept in a pre-heated oven at 55 ^{0}C for 48 hours. Oven temperature was maintained at 55^{0}C so that the organic matter of the sample are intact. In two sampling bottles $MgSO_4{\bullet}H_2O$ was added and stirred until lumps of sludge have been formed. The last two samples were dried in the sun for almost 5-6 days.

ANALYSIS TECHNIQUES

3.1 Pre-requisite Work

- **Collection** of wet sludge sample from the newly installed Sewage Treatment Plant.

- **Pre Heating of Sludge sample**

This was done by keeping the sludge sample in oven at 55^0C for 48 hours. Oven temperature was maintained at 55^0C so that the nutrients of the sample are intact. For Digestion the moisture content of the sample should be less than 1%, so the sample was heated in oven. [12]

Other methods were adopted for the removal of moisture from the sludge sample. They were:

- ***Quick Drying method for a fresh sludge sample***
  The fresh sludge sample was in liquid state which was difficult to dry in oven in the period of 24-48 hours. So, $MgSO_4$ was used for its quick drying. $MgSO_4 \cdot H_2O$ is reducing moisture in a quick time interval 25 to 30 min.
  Sample was taken in a beaker and same amount of MgSO4 was taken in that beaker and stirred. ($MgSO_4$ is to be preheated in the oven at any temperature above 500 ^{0}C). The solution is stirred continuously for 15 minutes. After some time lumps of sludge sample is formed with a white residue as $MgSO_4$ absorbs all water and only leaves the sludge which are formed as lumps.[12]

- ***Sun dried sample***
  This sample was obtained when it has been already dried by sun for several days. The same procedure was repeated for this sample also.

- **Determination of the moisture content**

After 48 hours in oven the sludge sample was kept in a desiccator and its moisture content was determined. This was done by taking a small amount of sample, weighing it and again heating in oven at 110^0C for 24 hours. After 24 hours the sample was taken out and weighed. Then the moisture content of the sample was determined. [13]

Weight of sample before heating: 10g
Weight of sample after heating : 9.953g
Moisture Content of sample : $\frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} * 100^0/_0$
`

: (10-9.953)/10 $*100^0/_0$

: $0.47^0/_0$

The moisture content of the sludge sample was 0.47%.
The moisture content of the fresh sludge sample with quick dring technique was found to be 1.24%
The moisture content of the sun dried sludge sample was found to be 2.67%.

- **Grinding and sieving of sludge sample**

After determining the moisture content the dry sludge is grinded in a small mixer up to 2-3 minutes. Then the whole sample is sieved through a sieve of 75 micron. The particles which passed and also which did not pass are kept separately in the desiccator so that no moisture is absorbed by the sludge.

- **Digestion of Sludge Sample**

The moisture content was optimum for the digestion process. Digestion was done in a microwave digester as it is very fast, efficient and accurate in the process. 0.2g of the sieved sample is taken in the pressure vessel with 4ml of HNO_3, 2ml of HF and 2ml of H_2O_2. The vessel is kept inside the digester and the temperature rod is inserted inside the vessel. Suitable programming is done and left for 2-3 hours. After getting the digested sample, it is taken in a beaker and diluted to 50 ml with distilled water. The sample is now ready for the characterization process. [14]

3.2 Methodology for the process of Digestion

Digestion means breaking down of complex particles into simpler particles. In case of sludge the municipal sewage is also broken down into simpler particles like methane, digestate. There are many methods of digestion but anaerobic digestion the most effective of them all. It reduces the quantity of sludge to be disposed of and also it provides energy in the form of methane gas. This increase the effectiveness of anaerobic digestion. Since the disposed sludge is treated, it poses a minimal threat to the surrounding environment.

Before the digestion process, sewage sludge is properly treated and processed. Some preliminary operations are..:

Grinding: Large particles present in the sludge are cut and shredded into small particles.

Screening: Here the coarse particles are removed.

Grit Removal: Grits which are not useful are removed.

Blending: The sludge is then mixed with chemicals and stored.

Thickening: water is removed from the sludge to make it thicker.

After performing these processes the sewage sludge is ready to be put inside the anaerobic digesters so that the anaerobic digestion can take place.

Principle

In this project work the digestion is done in a microwave digester. A microwave digester is a very fast way to digest and get the results. It is very effective against the normal digestion techniques. The principle behind the microwave digestion is when a sample is exposed to strong acids in an enclosed vessel and increasing its temperature by microwave irradiation then it increase the rate of thermal decomposition of the samples. When the samples are completely decomposed it becomes easy to detect the heavy metals in the solution through characterization techniques. [14]

Procedure

The moisture content was optimum for the digestion process. Digestion was done in a microwave digester as it is very fast, efficient and accurate in the process. 0.2g of the sieved sample is taken in the pressure vessel with 4ml of HNO_3, 2ml of HF and 2ml of H_2O_2. The vessel is kept inside the digester and the temperature rod is inserted inside the vessel. Suitable programming is done and left for 2-3 hours. After getting the digested sample, it is taken in a beaker and diluted to 50 ml with distilled water. The sample is now ready for the characterization process. [14]

3.3 Methodology for the measurement of pH

pH is the negative logarithm of concentration of hydrogen ions in a sample. pH varies from 6-8 for waste water sample but varies in case of sludge sample. In a sludge sample there can be many organic and mineral components which may increase or decrease the pH value of the sample. pH value of a sample can be more than 10 or even less than 5 depending on its content. There is no specific range within which pH value of a sludge sample can be obtained. Municipal as well as Industrial wastes affect the pH of a sludge sample. The pH in laboratory may differ than in the field conditions due to various reasons like reaction with sampling bottles, loss of gases, reaction with sediments in sampling bottles. Therefore pH value should be determined at the time of collection of sample. The pH of a sample can be obtained electrometrically as well as calorimetrically. Electrometrically pH analysis is more accurate than the latter as special apparatus is required for pH determination. Calorimetrical analysis can be used in case of general work.

Principle

The pH value is found out by measuring the electromotive force generated in a sample. It is made up of electrodes that are reactive to hydrogen ions. When is immersed in a test solution, by the reaction between the reference electrode and test solution a electromotive force is generated. That force measured in the instrument is pH. Usually pH measuring devices are high impedance voltmeters. Hydrogen gas electrode is the primary standard. Glass electrode with calomel electrode is generally used as reference potential provided by the saturated calomel electrode. The glass electrode system is based on a theory that an electrical change of 59.1 mV occurs when pH changes by 1 unit at 25 ^{0}C. The glass member forms a partition between the two liquids with varying hydrogen ion concentration and thus a potential is developed between the two sides of the membrane which is proportional to the difference in pH between the liquids. [15]

The apparatus are:

- **pH meter**: with reference or glass electrode
- **thermometer**: with a least count of 0.5 ^{0}C

Procedure

The instrument is normalized after its warm tip period. A buffer solution is used to determine the pH. The electrodes are checked in at least one other buffer solution of different pH value. The electrodes are taken out gently and wiped to be used in the solution. The electrodes are then dipped in the digested solution of the sewage sludge sample. After taking out the electrodes they are washed with normal water and then with distilled water. Then the experiment is repeated for two other samples.[15]

3.3 Methodology for determination of metals

To determine the metals in the digested sludge sample Atomic Absorption spectrometer is used. The underlying principle of this instrument is that a light beam is passed through a flame containing atomized particles into a monochromator which then leads to a detector which detects the presence of those atomized particles by measuring the light absorbed by the atomized elements in the flame. For determination of each metal a different source lamp is used with the wavelength identical to the wavelength of the metal which is to be found. This makes it free from spectral interference. The concentration of the element in the sample is directly proportional to the amount of energy of characteristic wavelength absorbed in the flame.

The presence of metals in the sludge can be beneficial or troublesome or toxic to the soil or to the plants or to animals which eat those plants depending upon the concentration. Flame and electro-thermal methods are generally applicable at low as well as moderate concentrations. The concentrations of all the metals are determined using Atomic Absorption spectrometer. [16]

Atomic Absorption Spectrometer consists of

- A light emitting source
- Burner : To atomize the digested sample
- A display unit
- Hollow Cathode ray lamps
- Pressure reducing valves

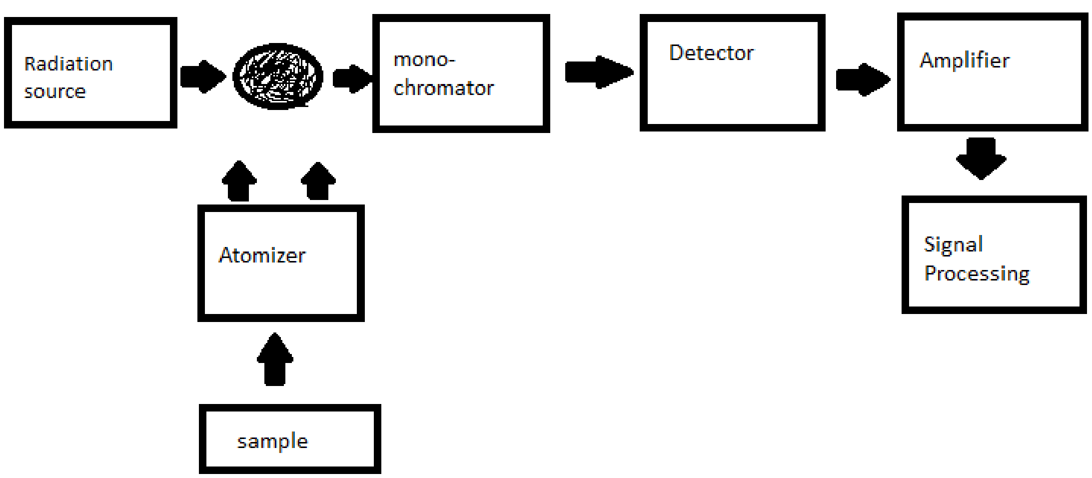

Fig 2 showing the schematic diagram of an AAS

The Atomic Absorption Spectrometer consists of an atomizer which converts the sample in to atoms. Many atomizers convert sample into atoms through flames. Some example of atomizers are flame atomizers, electro thermal atomizers, etc. radiation source of most of the AAS is hollow cathode lamps. These lamps are available in different wavelengths as per the requirement of the element. The hollow cathode lamps provide a constant supply of radiation so that the atomized elements can absorb the wavelength of the source and get detected.

When the atoms absorbs the particular wavelength then it is passed through a monochromator which passes only the element of required wavelength through it. After the element is passed through the monochromator it gets detected on a detector and gets amplified. Then by signal processing the concentration of the required element is determined.

Procedure

The sample is prepared according to the metal to which we are measuring. Manufacture's operation manual is studied and instrument is operated accordingly. Hollow cathode lamp of the required metal is installed in the instrument. As per manual is slit width is set for the metal. The instrument is ran for 20 minutes so that the energy source is stabilized. Then the instrument is calibrated with a blank solution and three standard solutions of required concentrations. The absorbance is recorded in the display unit. A graph of absorbance vs concentration is recorded in the display unit and it came out to be a straight line. Then the sample was analyzed and concentration of the required metal is recorded. [16]

Fig 1 showing the AAS at Environmental Engineering Lab

3.4 Methodology for determination of chemical characteristics

All the chemical characteristics of the digested sewage sludge sample was found with the help of a colorimeter (DRB 200 model) thermostat.

The following chemical characteristics were studied:

- pH
- Total Nitrogen
- Sulphates
- Total organic carbon
- Flourides

Fig 3. A colorimeter (DRB 200 model)

Procedure

The instrument is switched on. Manufacture's manual is read and the program is set for determination of TOC. Two samples are created. One blank for calibration of the instrument and other one with the desired sample. First the blank is inserted and the instrument is calibrated and then the vial containing the sample is inserted into the instrument. The required program is selected and the concentration of TOC is obtained. The same steps are repeated for sulphates, total nitrogen and fluorides.[17]

Results and Discussion

4.1 Tabulations

The samples are tested in the AAS and the concentrations of various metals and chemical characteristics are tabulated in Table 1 and Table 2.

Metals	**Sample 1 oven dried (ppm)**	**Sample dried with magnesium sulphate (ppm)**	**Sundried sample (ppm)**
Mercury	0.001	0.001	0.001
Copper	0.341	0.325	0.320
Zinc	3.733	3.210	2.986
Calcium	15.839	15.102	14.863
Lead	0.129	0.121	0.102
Chromium	0.479	0.423	0.399
Iron	16.308	15.962	14.214
Nickel	0.208	0.196	0.152
Magnesium	4.551	4.217	3.986
Aluminum	70.266	65.244	68.378
Silicon	105.54	50.201	109.245
Potassium	9.868	9.547	9.154
Phosphorus	5.324	5.109	4.214
Sodium	4.424	4.271	3.841

Table 1 showing the concentrations of metals in the three samples.

Chemical characteristics	Sample 1 oven dried	Sample dried with magnesium sulphate	Sun dried sample
pH	5.9	6.6	6.9
Fluoride (mg/g)	0.07	0.07	0.07
Total Nitrogen (mg/g)	11.00	10.21	9.24
Sulphate (mg/g)	0.40	0.68	0.32
TOC (mg/g)	6.24	5.21	8.20

Table 2 showing the chemical characteristics of all the three digested sludge sample.

The concentrations of metals and the chemical characteristics of the digested samples collected at different times are determined and tabulated in Table 3 and Table 4.

Chemical characteristics	8-11 am	12-3 pm	3-5 pm	Permissible value
pH	5.9	6.6	6.9	6.5-8.5
Fluoride (mg/g)	0.07	0.07	0.07	1.00
Total Nitrogen (mg/g)	11.00	10.21	9.24	12.5
Sulphate (mg/g)	0.40	0.68	0.32	1.20
TOC (mg/g)	6.24	5.21	8.20	10.0

Table 3 showing chemical characteristics of the digested sludge sample with time

Metals	8-11 am (ppm)	12-3 pm (ppm)	3-5 pm (ppm)	Permissible value (ppm)
Mercury	0.001	0.001	0.001	2.500
Copper	0.341	0.325	0.320	1.250
Zinc	3.733	3.210	2.986	5.000
Calcium	15.839	15.102	14.863	50.00
Lead	0.129	0.121	0.102	1.500
Chromium	0.479	0.423	0.399	2.500
Iron	16.308	15.962	14.214	30.254
Nickel	0.208	0.196	0.152	1.500
Magnesium	4.551	4.217	3.986	6.500
Aluminum	70.266	65.244	68.378	90.00
Silicon	105.54	50.201	109.245	150.0
Potassium	9.868	9.547	9.154	20.00
Phosphorus	5.324	5.109	4.214	10.00
Sodium	4.424	4.271	3.841	10.00

Table 4 showing metal concentration at different times

The concentrations of the nonmetals were found in the C.H.N.S laboratory of NIT Rourkela and their values are tabulated in Table 5. The values were given in terms of percentage of total weight volume of the sample. The weight volume of all the three samples are given in Table 6.The concentrations of nonmetals are then converted in mg/g in Table 7.

Nonmetals	**Sample1 oven dried (%)**	**Sample dried with magnesium sulphate (%)**	**Sun dried sample (%)**
Nitrogen	10.48	7.72	5.24
Carbon	4.36	3.78	3.21
Hydrogen	1.29	1.06	0.86
Sulphur	0.23	0.19	0.14

Table 5 showing the concentration of nonmetals in %

	Sample1 oven dried	**Sample dried with magnesium sulphate**	**Sun dried sample**
Weightvolume	8.32	7.48	6.96

Table 6 showing weight volume of the samples.

Nonmetals	Sample1 (mg/g)	Sample dried with magnesium sulphate (mg/g)	Sun dried sample (mg/g)
Nitrogen	2.62	1.93	1.31
Carbon	1.09	0.94	0.80
Hydrogen	0.32	0.26	0.21
Sulphur	0.05	0.04	0.03

Table 7 showing concentrations of nonmetals in mg/g

The N: P: K ratios of all three digested sewage sludge samples are calculated. It is calculated by dividing ppm concentration of the specific element. N: P: K ratio is the percentage of Nitrogen, Phosphorus and Potassium to the total weight. A fertilizer with an N: P: K ratio of 1:5:7 will have 1% of the total weight of the fertilizer as nitrogen and 5% as phosphorus and 7% as potassium.

	Sample1 oven dried (%)	Sample dried with magnesium sulphate (%)	Sun dried sample (%)
Nitrogen	1	1	1
Phosphorus	2.45	3.18	3.87
Potassium	8.63	11.33	11.91

Table 8 showing the N: P: K ratios of all the three samples.

The N: P: K ratios calculated for the sludge sample is then compared with the N: P: K ratios of various synthetic fertilizers and bio solids. The N: P: K ratios of several synthetic fertilizers are tabulated in Table 9 and various mined fertilizers and bio solids in Table 10 and 11 respectively.

Syntheic Fertilizers	**N (%)**	**P (%)**	**K (%)**
Calcium Nitrate	15	00	00
Ammonium Sulphate	21	00	00
Sulphur coated urea	30-40	00	00
Isobutylidene Diurea	31	00	00
Ammonium Nitrate	33	00	00
Ureaform	35	00	00
Methylene ureas	40	00	00
Urea	46	00	00
Anhydrous Ammonia	82	00	00
Ammonium Polyphosphate	10-11	34-37	00
Monoammonium Phosphate	11	48-55	00
Diammonium Phosphate	18-21	46-54	00
Potassium Nitrate	13	00	44
Super Phosphate	00	17-22	00
Triple Superphosphate	00	44-52	00

Table 9 showing N: P: K ratios of other fertilizers. [18]

Mined fertilizers	N (%)	P (%)	K (%)
Bird guano	11-16	8-12	2-3
Raw phosphate rock	00	3-8	00
Potassium Magnesium sulphate	00	00	22
Potassium Chloride	00	00	60

Biosolids	N (%)	P (%)	K (%)
Daily manure	01	00	00
Horse manure	01	00	01
Poultry manure	03	02	02
Bone meal	04	12	00
Fish bone	05	05	06
Milorganite	06	02	00

Table 10 and 11 showing N: P: K ratios of mined minerals and bio solids. [18]

Table 1 shows the concentration of metals in the three samples obtained from the Sewage Treatment Plant behind the V.S. Hall of Residence, NIT Rourkela. It is observed that the concentration of all the metals vary very little with the method of drying. The sun dried sample has the least concentrations of metals among all three. Therefore the sun dried method should be adopted if the sludge is to be used as a fertilizer. The same is true for Table 4 where the concentration of metals is low around 12 noon to 3 p.m. All the metals in Table 1 and 4 are in within prescribed limits of the IS codes and are therefore safe to be used as a fertilizer.

Table 2 shows the concentration of fluorides, sulphates, etc of all the three samples. All the values are very less for the sundried sample. As it is stable and dried in sun all the harmful characteristics of the sludge is destroyed in the heating process. In Table 3 the concentration of various chemical characteristics is displayed with respect of the time. Again in the time between 12 noon to 3 p.m. the values are at all-time low and is therefore can be used as a fertilizer.

Table 5 shows the concentration of nonmetals namely Carbon, Nitrogen, Hydrogen, Sulphur are determined as a percentage to the total weight volume of the sample. The nitrogen content of the oven dried sample is better than the other counterparts. All the concentrations of the non-metals are found in the C.H.N.S laboratory of NIT Rourkela. The concentration of nonmetals are converted from percentage to mg/g in Table 7.

In Table 8 the N: P: K ratios of all three digested sewage sludge samples are calculated. It is calculated by dividing ppm concentration of the specific element. N: P: K ratio is the percentage of Nitrogen, Phosphorus and Potassium to the total weight. A fertilizer with a N: P: K ratio of 1:5:7 will have 1% of the total weight of the fertilizer as nitrogen and 5% as phosphorus and 7% as potassium.

Potassium and phosphorus are present as K_2O_5 and P_2O_5. So to find the percentages of N P K we have to find the total solution weight. The empirical formulas are:

Percentage of Nitrogen = ((concentration of Nitrogen in ppm) / Total solution weight) * 100

Percentage of K as K_2O_5 = (((conc. of Potassium in ppm) / Total solution weight)*1.2046) *100

Where 1.2046 is the K to K_2O conversion factor.

Percentage of P as P_2O_5 = (((conc. of Phosphorus in ppm) / Total solution weight)*2.2914) *100

Where 2.2914 is the P to P_2O conversion factor.

After tabulating the N: P: K ratios of the digested sludge sample, the N: P: K ratios of other various synthetic fertilizers as well as bio solids are compared with the digested sludge sample and are tabulated in Tables 9, 10, 11.

CONCLUSION

Conclusion

Chemical characterization of all the sludge samples were performed. The pH value was found to be slightly acidic, ranging from 5-7. Concentrations of all the metals are found to be within the permissible limit prescribed by WHO.

The concentrations of fluoride, TOC, sulphates, total nitrogen are within the permissible value according to the guidelines of WHO. The concentrations of Mercury (0.001 mg/l), Iron (15.962 mg/l), Lead (0.129 mg/l) was found to be within the permissible value suggested by WHO.

The average N: P: K ratio of the sludge sample taken from Sewage Treatment Plant was found out to be 1: 3.2: 10.6. The N: P: K ratios of the sludge sample is compared with other synthetic fertilizers and bio solids. The sludge of the Sewage Treatment Plant has all the characteristics to be a good domestic fertilizer but its strong and pungent odor creates a problem in its land application.

REFERENCES

References

[1] www.fao.org

[2] Bao Yu, Jianbo Xu, Haiping Yuan, Ziyang Lou, Jinxian Lin, Nanwen Zhu "*Enhancement of anaerobic digestion of waste activated sludge by electrochemical pretreatment*" Fuel 130 (2014) 279–285.

[3] E. Sanchez,S. Montalvo, L. Traviesoa and X. Rodriguez "*Anaerobic digestion of sewage sludge in an anaerobic fixed bed digester*" Biomass and Bioenergy~ Vol. 9, No. 6. pp. 493-495, 1995

[4] S. Astals , C. Venegas , M. Peces , J. Jofre , F. Lucena , J. Mata-Alvarez , "*Balancing hygienization and anaerobic digestion of raw sewage sludge*" water research 46(2012) 6218 e6227.

[5] Andres Donoso-Bravoa, Maria Fdz-Polanco "*Anaerobic co-digestion of sewage sludge and grease trap: Assessment of enzyme addition*" Process Biochemistry 48 (2013) 936–940.

[6] Ole Pahl, Anna Firth, Iain MacLeod, Jim Baird "*Anaerobic co-digestion of mechanically biologically treated municipal waste with primary sewage sludge – A feasibility study*" Bioresource Technology 99 (2008) 3354–3364.

[7] Lahdheb Habiba , Bouallagui Hassib, Hamdi Moktar "*Improvement of activated sludge stabilisation and filterability during anaerobic digestion by fruit and vegetable waste addition*" Bioresource Technology 100 (2009) 1555–1560.

[8] E. Aymerich, M. Esteban-Gutiérrez, L. Sancho '*Analysis of the stability of high-solids anaerobic digestion of agro-industrial waste and sewage sludge*' Bio resource Technology 144 (2013) 107–114

[9] Sami Luste, Sari Luostarinen "*Anaerobic co-digestion of meat-processing by-products and sewage sludge – Effect of hygienization and organic loading rate*" Bioresource Technology 101 (2010) 2657–2664

[10] Feng Wang, Taira Hidaka, Jun Tsumori " *Enhancement of anaerobic digestion of shredded grass by co-digestion with sewage sludge and hyperthermophilic pretreatment*" Bio resource Technology 169 (2014) 299–306

[11] Mijung Kim, Yingnan Yang, Marino S. Morikawa-Sakura, Qinghong Wang,

Michael V. Lee, Dong-Yeol Lee, Chuanping Feng, Yulin Zhou, Zhenya Zhang "*Hydrogen production by anaerobic co-digestion of rice straw and sewage sludge* " International Journal of Hydrogen Energy 37 (2012)3142e3149

[12] Magdalena Olkiewicz, Martin Pablo Caporgno, Agusti Fortuny, Frank Stuber, Azael Fabregat, Josep Font, Christophe Bengoa "*Direct liquid-liquid extraction of lipid from municipal sewage sludge for biodiesel production*" Fuel Processing Technology 128 (2014) 331-338

[13] A.S.T.M code for waste water treatment

[14] Milestone Start D Operator's manual

[15] IS: 3025 (Part 23) – 1983, Methods Of Sampling And Test (Physical And Chemical) For Water And Waste Water, Part ii – ph Value

[16] Perkin Elmer AA200 model Instruction Manual

[17] Hach DR/890 Colorimeter Procedure's manual

[18] www.wikipedia.org

[19] Khanna Publisher, Garg S.K. , 1976 : Environmental Engineering - (2010 edition)

[20] Ole Pahl, Anna Firth, Iain MacLeod, Jim Baird "*Anaerobic co-digestion of mechanically biologically treated municipal waste with primary sewage sludge – A feasibility study*" Bioresource Technology 99 (2008) 3354–3364.

[21] Mishra, Falguni Krishna Prasad and Mahanty, Niladri Bihari (2012) "*Characterization of sewage and design of sewage treatment plant*". NIT Rourkela.