CHARACTERISATION AND TREATABILITY OF SOME MUNICIPAL SLUDGES

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DECLARATION

I hereby declare that the work embodied in dissertation entitled **"Characterisation and treatability of some municipal sludges"** is original piece of work and was conducted in the Department of Biotechnology and Environmental Sciences, Thapar University, Patiala. The matter presented in this thesis has not been submitted in part or full, to this or any other University/Institute for any degree or diploma.

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CERTIFICATE

This is to certify that the dissertation entitled, **"Characterisation and treatabilit municipal sludges"**, is an authentic work carried out by Mr. Vinod Kumar M.Tech. (Env. Sc. & Tech.) Thapar University, Patiala, during the year 2008-2009 fulfillments for the award of the Degree of Master of Technology and that the d has not formed the basis for the award previously of any degree, associate ship, fel any other similar title to any other university or institute.

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Vinod Kumar

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CHAPTER-1

INTRODUCTION

1.1 General

Sludge is the residual semi-solid material left from industrial, or wastewater treatment processes. When fresh sewage or wastewater is added to a settling tank, approximately 50% of the suspended solid matter will settle out in an hour and a half. This collection of solids is known as raw sludge or primary solids. The sludge will become putrescent in a short time, and must be removed from the sedimentation tank before it becomes septic.

This is accomplished in one of two ways. In an Imhoff tank, fresh sludge is passed through a slot to the lower story or digestion chamber where it is decomposed by anaerobic bacteria, resulting in liquefaction and reduced volume of the sludge. After digesting for an extended period, the result is called "digested" sludge and may be disposed of by drying and then landfilling. More commonly with domestic sewage, the fresh sludge is continuously extracted from the tank mechanically and passed to separate sludge digestion tanks that operate at higher temperatures than the lower story of the Imhoff tank and, as a result, digest much more rapidly and efficiently. *(http://en.wikipedia.org/wiki/Sludge)*

Excess solids from biological processes such as activated sludge process referred to as biosolids, is more commonly obtained after processing step such as aerobic composting. Industrial wastewater sludges are generated from biological or physical-chemical processes. Surface water treatment plants also generate sludge made up of solids removed from the raw water.

1.2 Backgrounds

Biosolids, the treated form of sewage sludge, have been in use in UK and European agriculture for more than 80 years, though there is increasing pressure to stop the practice of land application and this has been successful. Since the 1960s there has been cooperative activity with industry to reduce the inputs of persistent substances from factories. In the 1990s there was pressure in some European countries to ban the use of sewage sludge as a fertilizer. Switzerland, Sweden, Austria, and others introduced a ban. The European Commission encouraged the use of sewage sludge in agriculture because it conserves organic matter and completes nutrient cycles. Recycling of phosphate in this regard is especially important.

1.3 Amount and characteristics of sludge

Sludge consists of the organic and inorganic solids presents in the raw waste and removed in the primary clarifier, plus organic solid generated in secondary treatment and removed in secondary clarifier or in a separate thickening process. The inorganic fraction may be assumed to have a specific gravity of about 2.5, while the organic mater has specific gravity of 1.01 to 1.06, depending on its source.

The quality of solids in raw domestic wastewater is typically 90g/day per capita with the reported concentration of 100 to 350 mg/l depending largely on the flow. Community which contains major industries may vary from this value.

Of the solids in raw waste, approximately 60 percent may be expected to be removed in primary clarification. The remaining is either oxidized in biological treatment or incorporated in the biological mass. The biological solid generated in secondary treatment average 0.4 to 0.5 kg BOD applied in attached growth process.

The solid production will vary from day to day, will contain a lesser or greater amount of water, depending on the process involved. Mixed trickling filter and primary sludge may range from 5 to 10 percent solids and mixed primary and waste activated Sludge ranges from 2 to 5 % solids, while waste activated sludge alone may contain less than 1% solids under adverse circumstances. The moisture associated with sewage solids is in part free and separable by sedimentation, in part trapped in the interstices of floc particles and separable by mechanical dewatering, in part held by capillary action and separable by compaction. *(Metcalf & Eddy, inc., 2003,)*

1.3.1 Sources of sludge: The operations contributing to sludges during the treatment of wastewater are-

i) Screening (coarse solids, all types of organics and inorganic materials)
ii) Grid removal (grit and scum, heavier inorganic materials that settle)
iii) Pre-aeration (grit that is skimmed from surface)
iv) Primary sedimentation (primary sludge), etc.

Characteristics of primary sludge

- Contains both organic (BOD) and inorganic solids (sand, silt, etc.)
- 5% solids (95% water)

Characteristics of Secondary Sludge

- Dead bacteria
- Activated Sludge: 1% solids
- Trickling Filter & Rotating biological contractor: 5% solids

1.4 Sludge production

1.4.1 Historical Sludge Production

Des Moines Water Works (DMWW) has used a lime softening process to remove hardness since 1948. The chemical sludges had been pumped across the river from the treatment plant to 26.7 hectares of storage lagoons.

In 1991, DMWW began a structured approach to evaluate sludge dewatering techniques, potential for sludge marketing, and also evaluate government regulation of sludge reuse. The effort culminated in identifying dewatering of the daily sludge production as the solution to full- lagoon situation.

1.4.2 An illustration: To produce a clean effluent for disposal into waste bodies, three to four distant stages, that mimics the nature, are used in the waste water treatment plant operations.

Preliminary wastewater treatment extracts coarse solids and grit through screens and other filtering devices. This involves gravity sedimentation of screened wastewater to remove settled solids. Half of the solids suspended in wastewater are removed through primary treatment. The residual material from this process is a concentrated suspension called primary sludge, which will undergo further treatment to become biosolids.

Secondary wastewater treatment is accomplished through a biological process, which removes biodegradable material. This treatment process uses microorganisms to consume dissolved and suspended organic matter, producing carbon dioxide and other by-products. As the microorganisms feed, their density increases and they settle to the bottom of processing tanks, separated from the clarified water as a concentrated suspension called secondary sludge, biological sludge, waste activated sludge, or trickling filter humus.

Tertiary or advanced treatment is used when extremely high-quality effluent is required, such as direct discharge to a drinking water source. The solid residual collected through tertiary treatment consists mainly of chemicals added to clean the final effluent, which are reclaimed before discharge.

Combined primary and secondary solids comprise the majority of material used at municipal plants for biosolids production. Careful management throughout the entire treatment process allows plant operators to control the solids content, nutrient value and other constituents of biosolids.

Municipal Sludge-to-Biosolids Treatment Process

As indicated above sludges are generated from various unit operations in water and waste water treatment. The problems dealing with the sludges are complex because

i. It is composed of substances responsible for offensive character of untreated sewage.
ii. It is consists of organic matter that will decompose and become offensive.
iii. Only a small part of the sludge is solid matter and the rest is all water. The treatment employed for sludge treatment generally aims to stabilise the organic matter and reduction of volume of sludge by removing water.

Once sludge is treated properly, it has economic and environmental value, which makes it valuable for use as fertilizer in agriculture or other practices.

Besides, the factors such as 1) Pathogen levels, 2) Presence of harmful contaminants in industrial wastes are also addressed.

Stabilization accelerates the biodegradation of organic compounds, reduces the microbial population including pathogens, and renders the material microbiologically safe for agricultural use. Biological stabilisation uses aerobic or anaerobic treatment to reduce the organic content of solids. Chemical stabilisation creates process conditions that inhibit microorganisms, thereby slowing the degradation of organic materials and reducing odours. Thermal drying and composting can also be used to stabilise biosolids.

The presence of contaminants in the sludges arising from industrial discharges is a challenging problem and the deciding factor in determining the choice of an utilization/disposal option. Put simply, many industries have habitually used the sewer system as a convenient and low-cost way to discharge hazardous wastes. These contaminants accumulate in the biomass and sludge, and can render the material unfit for any beneficial use. The most common options used for disposal of this contaminated material are landfill or incineration, the cost of which is usually borne by the municipality rather than the hazardous waste generator. Biosolids utilisation is a good, environmentally sustainable option when the wastewater is from municipal sources only, or when a fully enforced industrial pre-treatment and discharge control system is in place.

The final concern is the water content of the product. Primary and secondary sludge generally contain not more than four percent solids, and the storage and transportation costs of this semi-liquid material limit the application to nearby farmland. The simplest method for removing water is gravity thickening, which involves concentration by simple sedimentation. Allowing sufficient time for solids to settle in tanks can increase suspended solids concentration to five or six percent. Thickening can also include flotation processes, gravity drainage belts, perforated rotating drums, and centrifuges. Nothing is added to biosolids during the gravity thickening processes.

1.5 Objectives of present study

In the state of Punjab, a few sewage treatment plants are commissioned in recent years and are being under operation. Hence the objective of the present study is to analyse the sludge obtained from treatment plants and look for some treatability studies on sludges for enhancing their quality. The sewage treatment plants located at Bhattian village (Ludhiana) (STP-1) and Phagwara city (STP-2) were selected. The study was performed during the period January-June, 2009 and the analysis of samples collected was carried out from February to May 09 at Environmental Laboratory, Thapar University.

CHAPTER-2

LITERATURE REVIEW

2.1 General

Sludges are one of the end products of wastewater treatment plants and are generated at primary settling tanks, chemical precipitation tanks, activated sludge plants and trickling filters. Inorganic sludges are harmless and the organic sludges (biological) require careful treatment and disposal, although its amount generated various from unit to unit.

The Literature available on sludge characterization, treatability is collected from internet, research magazines and reference books are presented in this chapter.

2.2 Research work presented

Asakura *et al.* (2008) determined the allowable ratio of waste sludge required to ensure an aerobic zone in the landfill, by investigating sludge permeability, which involved mixing sludge, for the major landfill waste in Japan. Parameters that influence on oxygen penetration depth with a simulation model accounting for both diffusion and convection were analysed. By keeping volumetric sludge content to below 25%, air convection and oxygen penetration depth of several meters were achieved in the modeling.

Lee and Liu (2008) Recovered sludge from wastewater of semiconductor-industries composed of agglomerates of nano-particles like SiO_2 and CaF_2. This sludge deflocculated acidic and alkaline aqueous solutions into nano-particles smaller than 100 nm. The sludge was potentially hazardous to water resources when improperly dumped. It caused considerable air-pollution when fed into rotary-kilns as a raw material for cement production. In this study, dried and pulverized sludge was used to replace 5–20 wt. % Portland cement in cement mortar. The compressive strength of the modified mortar was higher than that of plain cement mortar after curing for 3 days and more. They proved that Semiconductor sludge could be utilized as a useful resource to replace portion of cement in cement mortar, thereby avoiding the potential hazard on the environment.

Hirooka *et al.* (2008) used Nozzle-cavitation treatment was used to reduce excess sludge production in a dairy wastewater treatment plant. During the 450-d pilot-scale membrane bioreactor (MBR) operation, 300 l of the sludge mixed liquor was disintegrated per day by the nozzle-cavitation treatment with the addition of sodium hydrate and returned to the MBR, and the amount of excess sludge produced was reduced by 80% compared with that when sludge was not disintegrated.

On the basis of the efficiency of COD, Cr removal and the ammonia oxidation reaction, it was concluded that the nozzle-cavitation treatment did not have a negative impact on the performance of the MBR. The estimation of the inorganic material balance showed that when the mass of the excess sludge was decreased, the inorganic content of the activated sludge increased and some part of the inorganic material was simultaneously solubilized in the effluent.

You *et al.* (2008) studied the toxic effect of heavy metals on the nitrification mechanisms of activated sludge, by identifying the specific ammonia utilization rate (SAUR) inhibited by Pb, Ni and/or Cd shock loadings. Seven different heavy metal combinations (Pb, Ni, Cd, Pb + Ni, Ni + Cd, Pb + Cd, and Pb + Ni + Cd) with seven different heavy metal concentrations (0, 2, 5, 10, 15, 25, and 40 ppm, respectively) were examined by batch experiments. No significant inhibition in the nitrification reaction of the activated sludge was observed even when as much as 40 ppm Pb was added. Further, first order kinetic reaction could model the behavior of SAUR inhibition on activated sludge. On the other hand, the heavy metal adsorption ability in the activated sludge system was Pb = Cd > Ni. The specific adsorption capacity of activated sludge on heavy metal increased as the heavy metal concentration increased or the mixed liquid volatile suspended solid (MLVSS) decreased.

Lasheen and Ammar *(*2008) performed the metals speciation in all sludge samples obtained from the different Wastewater Treatment Plants (WWTPs), Mn, Ni and Zn were most abundant in the exchangeable, carbonate and Fe/Mn-oxide forms and showed the greatest degree of their mobility, while Cd, Cu, Cr and Fe were major in the organic and sulfide, and the residual form which, corresponded to the part of the metals which couldn’t be mobilized. They also found that Cement kiln dust significantly reduced the availability of metals by chemical modification of their chemical speciation into less available forms.

Curvers *et al.* (2008) did the work on importance of osmotic pressure in the overall dewaterability behavior of a biotic sludge. The property o biotic sludge difficult to dewater, was due to the presence of surface charges, which were due to the biological nature and the presence of weakly charged extra-cellular polymeric substances. In filtration and centrifugation experiments, charge related effects were partly neutralised through a controlled increase in the bulk ionic strength by the addition of NaCl. It was observed that an increase in the bulk ionic strength brings about an increase in the final solid volume fraction upon constant pressure filtration or centrifugation. Increasing the ionic strength did not result in a more classical filtration behavior. The results further suggested that with increasing total pressure, the relative importance of the osmotic pressure in the total resistance against compression diminishes, and that more structural effects dominate the solid stress at high pressures.

In the study performed by Yang *et al*.(2009) the viscosity of activated sludge played a major role on oxygen transfer and mass transport and consequently influenced the hydrodynamic regime and the system performance of a membrane bioreactor. Their study examined the rheological characteristics of activated sludge sampled in a pilot airlift MBR system for domestic wastewater treatment under ambient desert conditions, using a rotational rheometer equipped with cone-plate geometry. Both static and dynamic yield stresses were observed at the transition point of 25 s^{-1} of shear rate for an MLSS concentration range of 2.74–10.2 g/L. The static yield stress was not evaluated for activated sludge. In addition, a mathematical model to describe the rheological properties of the sludge was proposed. The relationships between viscosity, MLSS, temperature and shear rate were obtained statistically. The activation energy for the sludge in the airlift MBR was found to be 9.217 kJ $mole^{-1}$, and could be the cause of rapid fluctuation of transmembrane pressure with temperature variations.

Nelson and Sidhu (2008) analysed a model for the activated sludge process occurring in a biological reactor without recycle. The biochemical processes occurring within the reactor were represented by the activated sludge model number 1. In the past the ASM1 model had been investigated via direct integration of the governing equations. In this work they used continuation methods to determine the steady-state behavior of the system. In particular, they determined bifurcation values of the residence time, corresponding to branch points that were crucial in determining the performance of the plant.

Li *et al.* (2008) isolated a strain of sludge -lysing bacteria from waste activated sludge (WAS). In this study the species was found to be of new genus Brevibacillus (named Brevibacillus sp. KH3). The strain could release the protease which could enhance the efficiency of sludge thermophilic aerobic digestion. During the sterilized sludge digestion experiment inoculated with Brevibacillus sp. KH3, at pH 8 and 50 °C, the maximum TSS removal ratio achieved was 32.8% after 120 h digestion. In the case of un-sterilized sludge digestion inoculated with Brevibacillus sp. KH3, TSS removal ratio in inoculated-group was 54.8%, increasing at 11.86% compared with un-inoculation (46.2%). Brevibacillus sp. KH3 strain had a high potential to enhance WAS-degradation efficiency in thermophilic aerobic digestion.

Liu *et al*. (2008) investigated the feasibility of bioflocculant extraction from backwashing sludge to reduce its production costs. Results showed that ultrasound and base treatment could significantly enhance bioflocculant extraction efficiency. It was observed that bioflocculants extracted from sludge of pH 11.0 had no flocculating activity. In contrast, bioflocculants extracted from sludge of pH 5.0, named as M-1, had good flocculating activity. Further the flocculating activity of M-1, factors such as bioflocculant dosage, temperature and pH of the reaction solution were tested. The optimal conditions were 6.0 mg/l bioflocculant dosage and pH 5.0, at a temperature of 10 °C. The effectiveness of such bioflocculants in the decolorization of synthetically dyed wastewater was then examined. In flocculating methylene blue and fast blue in aqueous solutions, decolorization efficiency levels were 82.9% and 77.8%, respectively.

Pagnanelli *et al.* (2009) investigated the chemical mechanisms operating in cadmium and lead removal by activated sludge in sequencing batch reactors. Selective extraction and acid digestion of sludge samples denoted that both Cd and Pb were mainly present as surface-bound metals. Characterisation of sludge samples by potentiometric titrations and IR spectra suggested that carboxylic and amino groups were the main active sites responsible for the binding properties of the biomass. Simulation of metal speciation implemented with complexation constants determined in biosorption tests, showed that cadmium predominated as biosorbed species, while lead was mainly removed by precipitation.

Pérez *et al*. (2008) worked on Composting organic residue an alternative to recycling waste, as the compost obtained may be used as organic fertilizer. This study aimed to assess the composting process of rice straw and sewage sludge on a pilot-scale. Two piles, with shredded and non-shredded rice straw, were composted as static piles with passive aeration. Throughout the composting process, a number of parameters were determined, e.g. colour, temperature, moisture, pH, electrical conductivity, organic matter, C/N ratio, humification index, cation exchange capacity, chemical oxygen demand, and germination index. The results showed that compost made from shredded rice straw reached the temperatures required to maximise product sanitisation, and that the parameters indicating compost maturity were all positive; however, the humification index and NH_4 content were more selective. Under there conditions, the only limiting factor of agronomic compost utilisation was the increased soil salinity.

Fonts *et al*. (2008) made an effort with the Pyrolysis of sewage sludge in fluidized bed to produce bio-oil. The pyrolysis of three samples of anaerobically digested sewage sludge obtained from three different urban wastewater treatment plants was studied. The organic and inorganic matter composition, and the volatile and ash content of these sewage sludge samples were different. It was determined that the ash content of the raw material had an enormous influence on the sewage sludge pyrolysis. An increase in the ash content of the sewage sludge caused an increase in the gas yield and a decrease in the liquid and the solid yield. The increase of the volatile content of the sewage sludge caused an increase in the liquid yield. The H_2 content increased significantly with the ash content. The viscosity of the pyrolysis oils decreased when the ash content augmented. The chemical composition of the pyrolysis oils was also affected by the sewage sludge ash content. The oxygen-containing aliphatic compounds and the steroids decreased with the ash content, although its proportion in the sewage sludge liquid was also influenced by the organic matter composition of the sewage sludge samples.

Zinatizadeh *et al*. (2008) worked on control operation of a hybrid granular sludge reactor mainly related to biological behavior of the granules under different process conditions. In this study, a 1-l digester was used to examine biological activity of the granules grown in a hybrid anaerobic reactor (AHR). The biogas production process was modeled and analyzed with three-process variables viz., influent COD (3000, 6500 and 10,000 mg/l COD), biomass concentration (2000, 4000 and 6000 mg/l VSS) and initial alkalinity (200, 1100 and 2000 mg/l $CaCO_3$). Experiments were conducted based on a central composite face-centered design (CCFD) and analyzed using response surface methodology (RSM). In order to carry out a comprehensive analysis of the biogas production process, the indicative parameters viz., specific methanogenic activity (SMA), bicarbonate alkalinity produced-to-COD removed ratio. The maximum SMA was modeled to be 0.99 g CH_4-COD/g VSS d under CODin, initial bicarbonate alkalinity (BA) and biomass concentrations of 10,000 mg/l COD, 2000 mg/l $CaCO_3$ and 2000 mg/l VSS, respectively, while the observed value was 1.039 g CH_4-COD/g VSS d. The maximum COD removal was achieved at the condition when the influent COD was within the range of 4250–5250 mg/l and initial BA was more than 1100 mg/l $CaCO_3$. Initial BA and CODin played an important role in the production of bicarbonate alkalinity during the digestion process.

Hossain *et al.* (2008) aimed to characterise fundamental properties of the products of wastewater sludge obtained by pyrolysis. Wastewater sludge samples from different origin, including domestic, commercial and industrial sludges, were applied in the study. All samples were pyrolysed at a heating rate of 10 °C/min in a fixed bed reactor. The major gas species of pyrolysis, CO, CO_2, CH_4, C_2H_4, C_2H_6 and H_2, were monitored with gas chromatograph. The results showed that the energy required to pyrolyse wastewater sludge samples from room temperature to the carbonisation temperature of 550 °C varied according to the source and origin of the wastewater sludge and ranged from 1180 kJ/kg for the domestic to 730 kJ/kg and 708 kJ/kg for the commercial and industrial sludges, respectively. This study confirmed that in case of the commercial and industrial sludge samples, the recoverable calorific value from stoichiometric combustion of the pyrolysed bio-gas was sufficient enough to self-maintain the pyrolysis process. In case of the sample from domestic origin, the recoverable energy from combustion of the bio-gas compounds was lower than the energy required to heat the sample to the temperature of carbonisation.

Kwon *et al*. (2008) indicated that soil acidification is one of the rising land degradation issues facing world agriculture. The risk of acidification is currently being assessed as part of agriculture productivity and sustainability. This study was conducted to produce a new vermicomposting cast as a recycling resource derived from municipal sewage sludge. The earthworm, Eisenia Andrei, was fed under different conditions. The most suitable mixture was 77:23 w/w of sewage sludge and waste oyster shell. The vermicast products fulfilled the cast standards of Korea Ministry of Environment for all the parameters such as moisture content, pH, salinity, organic carbon, TKN, Phosphate, and heavy metals. Slowly released organic matter when added to soil improves the capacity of the soil to hold nutrients for plants, improves soil aeration for roots, and improves soil drainage. This product will be an addition to already-commercialized sludge vermicast as a higher value product.

Strezov and Evans (2008) worked on paper sludge a waste product from the paper and pulp manufacturing industry, for disposal in landfills. They found pyrolysis of paper sludge can potentially provide an option for managing this waste by thermal conversion to higher calorific value fuels, bio-gas, bio-oils and charcoal. The dominant volatile species of paper sludge pyrolysis at 10 °C/min were found to be CO and CO_2, contributing to almost 25% of the paper sludge dry weight loss at 500 °C. The hydrocarbons (CH_4, C_2H_4, C_2H_6) and hydrogen contributed to only 1% of the total weight loss. The bio-oils collected at 500 °C were primarily comprised of organic acids with the major contribution being linoleic acid, 2,4-decadienal acid and oleic acid. The high acidic content indicated that in order to convert the paper sludge to bio-oil, bio-diesel or petrochemicals, further upgrading would be necessary. The charcoal produced at 500 °C had a calorific value of 13.3 MJ/kg.

Aparicio *et al*. (2008) in their work, monitored some organic compounds in sludge samples from four wastewater treatment plants (WWTPs). All WWTPs used anaerobic biological stabilization of sludge. They showed that anaerobically digested dehydrated sludge and compost samples were most contaminated.

Pham *et al*. (2008) presented dealing with pre-treatment of wastewater sludge by ultrasonic waves at frequency of 20 kHz using fully automated lab-scale ultrasonication equipment. Different wastewater sludge solids concentrations, ultrasonication intensities, and exposure times of pre-treatment were investigated for the optimization of ultrasonication treatment process. The effect of ultrasonication treatment was assessed in terms of increase in soluble solids and the biodegradability of the wastewater sludge. In addition, rheological parameter of wastewater sludge, namely, viscosity was also measured to ascertain the suitability of wastewater sludge for conventional treatment processes as well as submerged fermentation. It was observed that the ultrasonication intensity and pre-treatment exposure time significantly affected the efficiency of the ultrasonication process followed by the solids concentration. The optimal conditions of ultrasonic pre-treatment were 0.75 W/cm^2 ultrasonication intensity, 60 min, and 23 g/L total solids concentration. The increases in soluble chemical oxygen demand and biodegradability, by aerobic sludge digestion process, in terms of total solids consumption increased by 45.5% and 56%, respectively. Nevertheless, the magnitude of viscosity values of ultrasonicated sludge was always lower than the raw sludge.

Jamali *et al*. (2008) developed fast microwave assisted extraction procedure and optimized for their eventual exploitation in the three-stage sequential extraction procedure proposed by modified BCR protocol. The effects of the microwave treatment on the extraction of Cd, Cr, Cu, Ni, Pb and Zn from untreated sewage sludge collected from Hyderabad city (Pakistan) were compared with those obtained from sequential BCR extraction procedure. In sequential BCR method, each extraction step takes 16 h, where as with the use of compromised microwave conditions, extraction steps could be completed in about 120 s, for each step, respectively. For measuring extractable by electrothermal atomic absorption spectrometry (ETAAS), and flame atomic absorption spectrometry (FAAS) were used. The validations of both extraction techniques were compared by the analysis of certified reference material of soil amended with sewage sludge (BCR 483). The results of the partitioning study of untreated waste water sewage sludge, indicated that more easily mobilized forms (step 1) were predominant for Cd, Ni and Zn (28.3, 28.4 and 43.7%), in contrast, the largest amount of Cd and Pb (66.4 and 72.8%) was associated with the iron/manganese oxide while Cr and Ni (71.2 and 38.7%) in organic matter/sulphide fractions. The overall metal recoveries in steps 1–3 (excluding residual step) were 95.3–104% of those obtained with the sequential BCR protocol. The accuracy of the proposed microwave extraction method (expressed as %R.S.D.) was lower than 10% for all metals.

Polak *et al.* (2008) compared the physico-chemical properties carried on humic acids extracted from sewage sludge and bottom sediments. The isolated humic acids were investigated by means of EPR, IR, UV/vis spectroscopic methods and elementary analysis AE. Humic acids were extracted from raw sewage sludge after the digestion process. The digestion process was found to have the most significant effect on the physico-chemical properties of humic acids.

The g-factor values for humic acid extracted from raw sewage sludge and from bottom sediments were lower in comparison to the humic acid extracted from sewage sludge after the fermentation processes. It was also observed that humic acids extracted from bottom sediments had a more aromatic character and contained less carbon, nitrogen and hydrogen than those extracted from the sewage sludge.

Peyronnard *et al*. (2009) worked on differential acid neutralization analysis, chemical analysis of selected leachates and mineralogical study to investigate the relationship between mineralogy and leaching behavior of hydroxide sludge doped in Zn and Cr stabilized/solidified by hydraulic binders. The leaching behavior of stabilized hydroxide sludge was controlled by the dissolution of portlandite (pH ~ 12) followed by the dissolution of AFt/AFm and hydrogarnets (pH between 12 and 10) and finally the dissolution of ettringite and of the siliceous matrix of C–S–H (pH < 10). The zinc behavior was independent of the main components and was controlled by the dissolution of calcium hydroxizincate and its reprecipitation as hydroxide or its adsorption on C–S–H. Chromium release was linked to the sulfate due to a substitution in AFt/AFm phases. The proposed combination of tests was highly pertinent to establish the links between mineralogy and leaching behavior.

Uggetti *et al*. (2009) worked on optimization of sludge management to reduced sludge handling costs in wastewater treatment plants. Sludge drying reed beds appear as a new and alternative technology which has low energy requirements, reduced operating and maintenance costs, and causes little environmental impact. The objective of this work was to evaluate the efficiency of three full-scale drying reed beds in terms of sludge dewatering, stabilization and hygienisation. Samples of influent sludge and sludge accumulated in the reed beds were analysed for pH, Electrical Conductivity, Total Solids (TS), Volatile Solids (VS), Chemical Oxygen Demand, Biochemical Oxygen Demand, nutrients (Total Kjeldahl Nitrogen (TKN) and Total Phosphorus (TP)), heavy metals and faecal bacteria indicators. There was a systematic increase in the TS concentration from 1–3% in the influent to 20–30% in the beds, which fits in the range obtained with conventional dewatering technologies. Progressive organic matter removal and sludge stabilization in the beds was also observed (VS concentration decreased from 52–67% TS in the influent to 31–49% TS in the beds). Concentration of nutrients of the sludge accumulated in the beds was quite low, and heavy metals remained below threshold concentrations. E. coli concentration was generally lower than 460 MPN/g in the sludge accumulated in the beds.

Lee and Welander (1999) looked for the possibility of minimizing sludge production in aerobic wastewater treatment through manipulation of the ecosystem so that most of the bacterial biomass produced was consumed by predating protozoa and metazoa studied. The study was carried out on different pulp and paper industry wastewaters. In all of the experiments, the wastewater was first subjected to treatment in a completely mixed, aerobic reactor without biomass retention, favouring the growth of fast-growing dispersed bacteria consuming the readily biodegradable organic matter in the wastewater. After treatment at this stage, the wastewater was lead to a reactor for growth of predators consuming the bacteria. The total suspended solids (TSS) content of the wastewater increased considerably in the first reactor because of the production of bacterial biomass after which it was reduced significantly in the second reactor in which large amounts of different types of protozoa and metazoa developed. The apparent sludge yield in the processes varied between 0.01 and 0.23 kg TSS/kg COD removed, which was considerably lower than the yields generally obtained for treatment of similar wastewaters in conventional treatment processes.

Kuo *et al*. (2005) presented the work on the removal of copper from industrial sludge by traditional and microwave acid extraction. The experimental findings revealed. That the most economical traditional extraction conditions were the use of 1N sulfuric or nitric acid for 60 min at an S/L ratio of 1/20; however, at an S/L ratio of 1/6, the extraction time needed to achieve the same copper removal efficiency was increased to 36 h. A comparison of the results of microwave-assisted (microwave only) and microwave-enhanced (microwave with addition of active carbon) acid extraction demonstrated that under both conditions, S/L ratio = 1/6 and 1/20, adding active carbon shortened the extraction time required to achieve 80% copper extraction efficiency from 20 to 10 min. These experimental results indicated that the most important factors affected microwave acid extraction were the addition of a microwave absorber, the microwave power input and the S/L ratio. The sludge particle size did not significantly affect the copper extraction. The results revealed that sulfuric acid was an effective extractant and that the copper fraction in the extracted sludge shifted from being mostly bound to the Fe–Mn oxides and organic matter, to being mostly bound to organic matter and remaining as a residue during acid extraction.

Kim et al. (1995) worked on the industrial sludge generated by U.S. Army installations containing oil, grease. Metals, and energetic compounds; and was frequently classified as hazardous waste. The sludge management practices at four U.S. Army installations were studied to assess the current status of industrial waste treatment; to make recommendations for the improvement of sludge management systems by applying proven technologies; and to determine future needs for research and development of treatment technologies. Technologies that could improve the Army's industrial sludge management such as: process water reuse, electrowinning, solvent recycling, inventory control, optimal chemical use, electrochemical precipitation, membrane separation, crystallization, and dewatering were reported. This report made specific promising recommendations for further development such as: regeneration of activated carbon containing energetic waste, closed loop water treatment and reuse technologies, new generation sludge thickening and dewatering technologies, and biological treatment and separation of heavy metals.

Perkins et al. (2003) made an attempt from the sludges of industrial wastewater to produce soluble organic products and gases in a nitrolysis reaction. The conversion of industrial excess sludge reached 80% by mass. The most instrumental operating parameters in increasing this conversion were reaction temperature and acid/sludge ratio in the reactor. The reduction in mass and volume of the excess sludge showed promise in reducing the liability and cost associated with disposal. The production of organic acids (e.g., acetic acid) was also demonstrated. The reaction rate of the process was compared to a previously developed model, showing good agreement. The stoichiometry of the process was investigated, showing more than 90 mg of acetic acid and more than 50 mg of formic acid produced per gram of industrial excess sludge reacted.

Kim and Swanson (1997) worked on wastewater sludge for the U.S. Forces, Korea (USFK) and the Eighth U.S. Army (EUSA) disposed at landfills by Korean contractors. Technical alternatives for improving sludge management include mobile mechanical dewatering, alkaline stabilization, composting, reed bed use, and autothermal thermophilic aerobic digestion (ATAD). Technologies were chosen for review based on their ability to comply with both U.S. and Korean regulations and to achieve long-term improvement, and their availability in Korea. The study recommended: (1) Use of mobile mechanical dewatering followed by either aerated static pile composting, windrow composting or alkaline stabilization for the Western Corridor DPW (2) Discontinuation of the secondary treatment at the Yongsan DPW (3) Conversion of the Camp Humphreys' sand-drying beds to reed beds (4) Establishment of a long term goal to convert Camp Casey's aerobic digester to ATAD and using the biosolids as a soil supplement at Camp Casey.

Miller et al. (1995) described the Metals Recovery from Industrial Sludge Program. The program objective was to identify processes for reclaiming metals from a mixed, metal-bearing, waste sludge produced by the Industrial Waste Treatment Plant at Tinker AFB and other facilities where similar waste treatment processes were used. Metal separations appeared promising through selective chemical precipitation processes. Other technologies, including electrowinning, electrodialysis, and wet air oxidation may be combined with chemical precipitation to offer a feasible metals recovery process.

The operations which are generally used to improve the treatability of sludge include sludge grinding and sludge blending to make the sludge more uniform. Sludge grinding to reduce wear of pumps and sludge storage to reduce the required capacity of other processing facilities.

2.3 Methods of treatment and disposal of sludge

The methods used to treat and dispose of sludges generally available are, 1) Thickening or Concentration, 2) Digestion or Stabilisation, 3) Conditioning, 4) Dewatering, 5) Drying, 6) Incineration or Thermal reduction, 7) Ultimate disposal, Thickening, Conditioning, Dewatering, and drying are used primarily to remove moisture from sludges, while digestion and incineration are used to treat the organic matter present in the sludge.

2.3.1 Sludge thickening

This is a procedure used to increase the solid contents of sludge by removing a portion of liquid fraction. If waste activated sludge with 0.8 percent solids contents can be thickened to a content of 4 percent solids, then a five fold decrease in sludge volume is achieved. Sludge thickening is commonly achieved by 1) Gravity Thickening 2) Flotation Thickening, 3) Centrifugation.

Centrifugation

In this process centrifuges which cause settling of sludge particles under the influence of centrifugal forces. Centrifuges are used for both thicker and dewater sludges. A basket centrifuge type operates on a batch basis. The liquid sludge is introduced into a vertically mounted spinning bowl. The solids accumulate against the wall of bowl. The centrate is decanted. When the solids holding capacity of the bowl of the machine has been achieved, the bowl decelerates and a scraper is positioned in the bowl to remove the accumulated solids. The method of centrifugation thickening involves high maintenance power costs. Therefore the method is usually adopted at large sewage treatment plants.

2.3.2 Sludge Dewatering

Sludge dewatering is a physical unit operation used to reduce the moisture content of sludge. It is carried out:

a. To reduce the cost for trucking sludge to the ultimate disposal site.
b. To make the sludge easier to handle than liquid sludge.
c. Prior to the incineration of the sludge to increase the calorific value.
d. To render the sludge totally odourless and non-putrescible.

Several methods are available for dewatering sludge. The simplest method is to spread the digested sludge on an open bed of sand and allow it to remain there till it dries; drying takes place by a combination of evaporation and gravity drainage. A piping system built under the sand bed collects the water that drains from the sludge. A cross section a typical drying bed, is shown in figure 2.1

Sludge drying beds usually consist of about 200mm of sand placed on top of a layer of gravel or crushed stone, the pipes that make up the under drain system are placed below the gravel or crushed stone layer. Since a relatively large amount of land area may be required to construct the sand beds, this method of sludge drying is more common used in rural or suburban communities than in more densely populated urban areas.

Sludge is applied to the sand beds to depths up to 300mm. A typical dewatered sludge cake, as it is called, has solids content of about 40%, this level of dewatering can be obtained after about 6 weeks of drying. At this point, the sludge can be removed from the sand manually with a pitchfork or with machinery such as a front end loader. Sometimes it is necessary to build a glass enclosure, much like a green house, over the sludge beds to protect the sludge from rain and to reduce the drying time in cold weather.

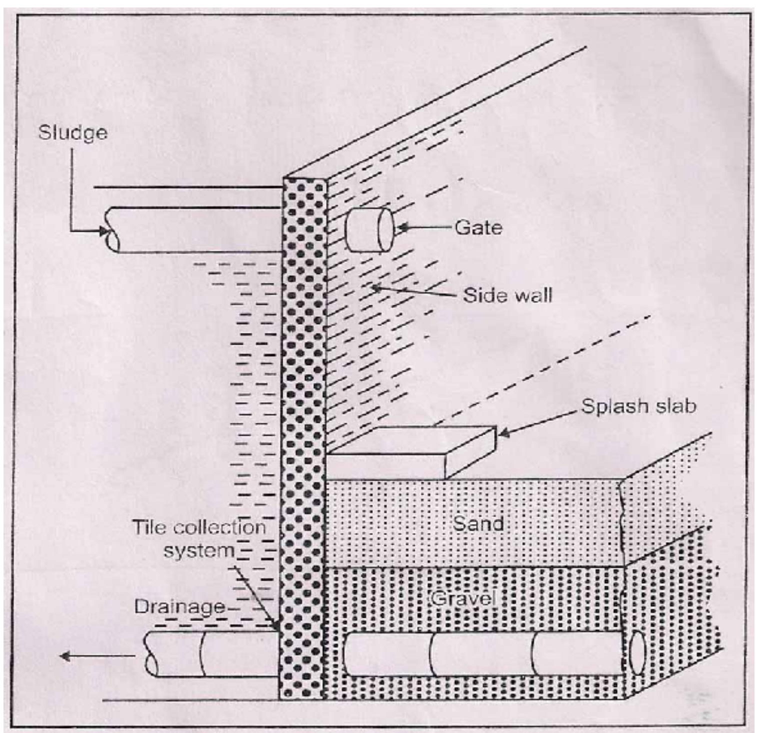

Figure 2.1 A section of sludge drying bed

As pointed out in the review of literature, it is necessary to treat the sludges generated at the wastewater treatment plants and several methods are available to achieve the same.

CHAPTER-3

MATERIAL AND METHODS

This chapter discusses the materials used and methodology adopted during the study.

All the chemicals used and reagents employed were of analytical grade with sufficient purity. The calibration curves were prepared prior to the estimation of unknown concentration (P, N etc.) and used throughout the study.

3.1 Collection of sludge

Sludge samples were collected from municipal sewage treatment plant (STP-1 and STP-2) located at Bhattian village in Ludhiana and Phagwara, Punjab. The treatment plants were based on UASB technology. Samples were collected monthly in precleaned, sterlised, polyethylene bottles of 2litres capacity. The analysis of the samples was performed for various sludge characteristics in the Environmental Science Laboratory, Thapar University during the period January-June 2009.

3.2 Treatment of sludge

The raw sludges collected above were treated to improve the quality by using two unit operations such as 1) centrifugation, 2) sludge drying beds, at the Laboratory.

3.2.1 Centrifugation

In this method, sludge samples of volume 300 ml were placed in cups and were rotated at a speed of 8000 rpm for 10 minutes. Supernatants were decanted and the solids settled the bottoms in the cups were used for further estimation.

3.2.2 Sludge drying beds

The sand available at Thapar campus was sieved and ensured not to contain any lumps etc. a sludge drying bed of size 12×6 inches and a thickness 1.5 inch was constructed in a plastic tray, with a provision for outlet at the bottom to collect treated effluent. Care was taken to arrange the fine sand at the top and the coarse sand at the bottom of the bed. The raw sludge was placed manually on the top of the drying bed; retained sludge was scraped off after 24 hours of drying and was used for estimation of quality parameters.

3.3 Physico-chemical analysis of the samples

The physical and chemical parameters of the raw sludges samples collected from STP-1 and STP-2 monthly and also the treated sludge samples by centrifugation and sludge drying beds were estimated by following the procedure given in standard methods for examination of water and wastewater, (APHA,1994).

1. pH estimation

The pH of samples was estimated using a 'EUTECH CYBERNETICS Model pH scan meter. The pH meter was first calibrated with buffer solutions of pH 4.7 and 9.2 and then pH of samples was determined.

Procedure

Take 1 gm sludge in conical flask and make up the volume to 100ml with the distilled water. Now set it at shaker for proper mixing for 30 minutes. After mixing take its pH by electronic pH meter.

2. Estimation of total alkalinity

This was estimated by titrating the sludge with $\frac{N}{50}$ H_2SO_4 against methyl orange or phenolphthalein indicator.

3. Estimation of $HCO3^-$, $CO3^{-2}$

Estimation: The estimation as done indirectly by making use of the total alkalinity readings obtained as above.

4. Moisture content

Procedure

Take the weight of paper and spread some sludge on it and take total weight then put in into glass Petri plate and set for 24 hours in oven at temperature 103-105$^{.c}$. After 24 hours take it and weight it, to calculate the moisture content in sludge.

5. Volatile solid (VS)

These are estimated by igniting the known weight of dried sludge at 550$^{.c}$ to a constant weight.

The determination is useful in wastewater treatment plant operation because it offers a rough approximation of the amount of organic matter present in the solid fraction of wastewater, activated sludge, and industrial wastes.

6. Total solid

A well-mixed sample is evaporated in a weighted dish and dried to constant weight in an oven at 103 to 105$^{\cdot}$c.The increase in weight over that of the empty dish represents the total solids.

7. Total nitrogen

A major part of nitrogen in sludge is intimately associated with organic matter. As the sludge organic matter gradually decomposes, the organic nitrogen gets converted into others forms such as NH_3 and NO_3^- which can be relatively easily taken up by plants. A general approximation of the sludge content can be had from the organic matter content for the latter has been found to contain ,on an average 5% nitrogen .So % organic matter × 0.05 =percent total nitrogen.

Total nitrogen was estimated by following digestion of sample with Hibberd’s mixture.

8. Total phosphorus

Phosphorus was estimated after perchloric acid digestion of sludge sample and development of colour with ammonium molybdate and stannous chloride reagents.

CHAPTER-4

RESULT AND DISCUSSION

This chapter presents the results of the study conducted and a discussion on the results obtained. Although the study period was from January-June 2009, the physico-chemical analysis of raw sludge from STP-1 and STP-2 and treated sludge after centrifugation and sludge drying beds are presented in Table 4.1-Table 4.8 for February-May 2009. Generally in the municipal sludges heavy metals are not expected.

Hence no effort was made to analyse them in the samples collected.

4.1 pH and alkalinity

The pH value indicates the intensity of acidity and alkalinity and measures the hydrogen ion concentration of a sample. The pH value of the sludges varied from 8.11 to 8.85 at an average of 8.48 indicating the sludges were alkaline.

Alkalinity is a measure of the ability of sample to neutralise acids. The acceptable limit in the water is 200 ppm. In the absence of alternate water sources, alkalinity up to 600 ppm is acceptable. The alkalinity data in the present study for the raw sludges varied from 60 to 488 ppm. Alkalinity due to bicarbonate was found in the range 48-488 ppm although carbonate contribution was very less. These values agree with pH values measured.

TABLE 4.1 PHYSICO-CHEMICAL PROPERTIES OF RAW SLUDGE FROM STP-1 (FEB, 2009)

Parameters	**Concentration**
pH	8.11
CO_3^{-2}	Nil
HCO_3^-	244 ppm
Moisture content	92.85%
Total solids	7.15%
Volatile solids	44.55%
Total nitrogen	102.18mg/l
Total phosphorus	2.532mg/l

TABLE 4.2 PHYSICO-CHEMICAL PROPERTIES OF RAW SLUDGE FROM STP-2 (FEB, 2009)

Parameters	**Concentration**
pH	8.40
CO_3^{-2}	Nil
HCO_3^{-}	268.4 ppm
Moisture content	97.23%
Total solids	2.77%
Volatile solids	40.34%
Total nitrogen	108.48mg/l
Total phosphorus	1.508mg/l

TABLE 4.3 PHYSICO-CHEMICAL PROPERTIES OF RAW SLUDGE FROM STP-1 (MARCH, 2009)

Parameters	**Concentration**
pH	8.81
CO_3^{-2}	Nil
HCO_3^{-}	61 ppm
Moisture content	91.39%
Total solids	8.60%
Volatile solids	41.40%
Total nitrogen	106.85mg/l
Total phosphorus	2.431mg/l

TABLE 4.4 PHYSICO-CHEMICAL PROPERTIES OF RAW SLUDGE FROM STP-2 (MARCH, 2009)

Parameters	**Concentration**
pH	8.85
CO_3^{-2}	Nil
HCO_3^{-}	48.8 ppm
Moisture content	96.96%
Total solids	3.03%
Volatile solids	40.34%
Total nitrogen	111.52mg/l
Total phosphorus	0.828mg/l

TABLE 4.5 PHYSICO-CHEMICAL PROPERTIES OF RAW SLUDGE FROM STP-1 AND TREATED SLUDGE (APRIL, 2009)

Parameters	**Raw sludge concentration**	**Sludge After centrifugation concentration**	**Sludge After drying beds concentration**
pH	8.18	8.19	8.21
CO_3^-2	Nil	Nil	Nil
HCO_3^-	488mg/l	477.1mg/l	475mg/l
Moisture content	84.74%	71.64%	8.24%
Total solids	16.25%	28.35%	91.76%
Volatile solids	39.30%	28.71%	31.77%
Total nitrogen	102.65mg/l	52.96mg/l	58.09mg/l
Total phosphorus	1.443mg/l	0.499mg/l	0.492mg/l

TABLE 4.6 PHYSICO-CHEMICAL PROPERTIES OF RAW SLUDGE FROM STP-2 AND TREATED SLUDGE (APRIL, 2009)

Parameters	**Raw sludge concentration**	**Sludge After centrifugation concentration**	**Sludge After drying beds concentration**
pH	8.39	8.31	8.43
$CO_3^{-}2$	Nil	Nil	Nil
HCO_3^{-}	341.6mg/l	322.4mg/l	335.1mg/l
Moisture content	95.44%	74.23%	6.13%
Total solids	4.55%	25.76%	93.87%
Volatile solids	35.30%	22.41%	25.07%
Total nitrogen	113.62mg/l	70.69mg/l	74.89mg/l
Total phosphorus	2.938mg/l	1.250mg/l	0.928mg/l

TABLE 4.7 PHYSICO-CHEMICAL PROPERTIES OF RAW SLUDGE FROM STP-1 AND TREATED SLUDGE (MAY, 2009)

Parameters	**Raw sludge concentration**	**Sludge After centrifugation concentration**	**Sludge After drying beds concentration**
pH	8.07	8.04	8.04
$CO_3^{-}2$	Nil	Nil	Nil
HCO_3^{-}	157mg/l	150.4mg/l	154.8mg/l
Moisture content	81.29%	70.71%	4.63%
Total solids	18.71%	29.29%	95.37%
Volatile solids	37.50%	26.83%	30.61%
Total nitrogen	104.28mg/l	65.56mg/l	63.69mg/l
Total phosphorus	1.223mg/l	0.266 conc.	0.259mg/l

TABLE 4.8 PHYSICO-CHEMICAL PROPERTIES OF RAW SLUDGE FROM STP-2 AND TREATED SLUDGE (MAY, 2009)

Parameters	**Raw sludge concentration**	**Sludge After centrifugation concentration**	**Sludge After drying beds concentration**
pH	8.35	8.30	8.21
$CO_3^{-}2$	Nil	Nil	Nil
HCO_3^{-}	170mg/l	156.6mg/l	162.3mg/l
Moisture content	94.30%	75.89%	2.77%
Total solids	5.70%	24.11%	97.23%
Volatile solids	34.60%	23.37%	28.09%
Total nitrogen	112.22mg/l	69.75mg/l	70.69mg/l
Total phosphorus	1.298mg/l	0.323mg/l	0.338mg/l

4.2 Moisture content and types of solids

The moisture content and total solids content play a major role in the sludges, commercial foods etc. Less moisture facilitates sludge treatment method such as incineration. The total solids measure the capacity of containers required to transport or store the sludges. The type of solids expected in primary settling is suspended, whereas in secondary settling is flocculating type.

Moisture content of sludges analysed was found in the range 91-97%. The total solid contents were varying (2-9%) different months, the minimum during February.

Volatile solids are useful in the control of wastewater treatment plant operation as they indicate rough estimation of organic matter. Volatile solids estimated varied between 40 to 44% during the first two months.

Fonts et al (2008) while working on Pyrolysis of sewage sludge in fluidized bed to produce bio-oil considered similar type of estimations.

4.3 Total nitrogen and total phosphorous

Total nitrogen consists of Ammonical N_2 and Org-N. The forms of N present indicate the status of decomposition of waste. Phosphorus is generally contributed by detergents etc. in domestic sewage.

Nitrogen and Phosphorus are fertilizing elements. To avoid, eutrophication the total Phosphate shouldn’t exceed 0.05 mg/l in a stream.

Nitrogen and Phosphorus help in building protoplasm of microbial cells in biological treatment. Domestic sewage supports adequate nutrients and the industrial wastes lack the nutrients.

Total Nitrogen in the sample ranged between 102 to 112 mg/l and the total phosphorus was found varying between 0.176 to 0.415 mg/l.

Nitrogen and Phosphorus in sludges is significant to decide its application as a fertilizer to the agricultural soil.

Uggetti et al (2009) reported the optimization technique for reducing the sludge handling cost and considered the nitrogen and phosphorus estimation from the sludges.

On the light of observation in section 4.1, 4.2 & 4.3 the raw sludge analysis showed a favorable pH, adequate support of nutrients.

4.4 Performance of STP-1 AND STP-2

Due to the intense activities, drainages, it is speculated that the sewage at Phagwara (STP-2) is more polluted than that at Bhattian (STP-1). However, this is not supported by the analysis results (Total solids=7.15% and volatile solids=44.55% for STP-1 as against 2.77% and 40.34% for STP-2)

The performance of a wastewater treatment plant depends on the mode operation, quantity of waste to be treated and the type of reactors installed. As an example, thickening filters are operable for toxic waste and shock loadings whereas the cost of maintenance is highest with activated sludge process. In general, advanced reactors are superior to conventional reactors. Such type of performance of treatment plants is reported by several authors (Perez, 2008 ;Li et al, 2008 ;nelson et al ,2008).

4.5 Treatability of Raw sludge

Treatability studies were performed for raw sludges by centrifugation and drying beds to minimize the objectional nature and improve the final quality. The results of physico-chemical analysis of treated effluent is presented in Table 4.5-Table 4.8.

4.5.1 Treated sludge quality after centrifugation

The alkalinity of the treated effluent reduced in comparison to raw sludge (from 488-477 mg/l 477.1 mg/l at STP-1 for April, 2009). The total solids from 16.25% to 28.35% and the volatile solids dropped to 28.71%. Total Nitrogen and Total Phosphorus also reduced indicating that solids reached the bottom of centrifuging cup could be possibly organic matter. Similar type of results was obtained for all the samples analysed during the study period.

The results indicated that clearly the method of centrifugation is helpful in achieving the improved quality of sludge. But the method is advocated due to intense power requirement to large size treatment plants. (Modi, 2001).

4.5.2 Treated sludge quality by drying beds

The alkalinity in the treated effluent reduced from 157 mg/l to 154.8 mg/l of $caco_3$. The solids content range from 18.71% to 95.37%. (STP-1 for May, 2009). Volatile solids in the treated effluent dropped from 37.5% to 30.61%. Nutrients like total N and total P showed clearly a decline for the treated effluent. Similarly observations were recorded for all the samples analysed during the study period.

Sludge drying beds are viable at locations having sufficient space, adequate temperature. The maintenance is done by local workers. Several rescorless have tried to treat waste sludges (Metcalf & Eddy, 2003). In my case also, sludge drying beds are found enhancing the sludge quality.

4.5.3 Comparison of performance of centrifugation and sludge drying beds

Both the methods of sludge treatment were found enhancing the quality. In a few cases, it was found sludge drying beds are better (91.76% total solids) as against 28.35% for centrifuging for treated sludge, although nitrogen and phosphorus were not improved much. During the study the sludge drying beds didn’t pose any problem was better as it required less maintenance.

CHAPTER-5

CONCLUSION

Based on the study performed on characterization and treatability of some sludges, the following conclusion were made-

1. The raw sludge at STP-1 and STP-2 has favorable pH, adequate nutrients etc. This could be a source of fertilizer for agriculture/soil conditioner.

2. Raw sludge at STP-2 has more objection than that of STP-1 (although my results couldn't reveal). The municipality needs to play more attention during waste treatment and ultimate disposal.

3. Sludge drying bed is a better treatment option for enhancing the quality of raw sludge in comparison to centrifugation. More emphasis is required for popularizing the same.

In a nut shell, improving sludge quality is a necessity for the city municipality prior to the ultimate disposal. Economical & viable methods of sludge treatment are to be devised.

Future scope:

1. A comparative analysis of performance of STP-1 and STP-2 is essential.

2. Sludge drying bed is an economical method for sludge treatment optimizing the dimensions of bed, operating condition to maximize the quality of sludge is required.

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