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(Research Article)

Characterization of sewage sludge and biomass ash mixture as future geotechnical material

Anhar Yousuf Wani [1, *] and Shamshad Alam [2]

[1] *Department of Civil Engineering, School of Engineering and Technology, Sharda University, India.*
[2] *Civil Engineering Department, College of Engineering, Jazan University, Kingdom of Saudi Arabia.*

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Abstract

To reduce the environmental load due to waste generation, there is an urgent need of utilizing the industrial/municipal waste in the bulk. There is a large scope of utilizing the bulk amount of waste as geotechnical material. Several studies have been made to utilize the industrial waste such as fly ash, slag, red mud, mine overburden *etc.* as geotechnical material, however, the sewage sludge did not get much attention. So, this research has been presented as a preliminary study which includes the physical, chemical, and microstructural property of sewage sludge for futuristic geo-material. Further, the biomass ash has been added with the sewage sludge to know its effect. The test result shows that the sewage sludge contains high concentrations of chromium, mercury and nickel. Dewatered municipal sewage sludge (80%) stabilized with biomass ash (20%) was used as a soil amendment, to predict the behavior of soil under a controlled environment. The application of stabilized sewage sludge over soil sample resulted in a significant increase in pH and electrical conductivity of the soil sample. The effect of stabilized sewage sludge over macronutrients and micronutrients present in soil was also determined and the results of statistical analysis revealed that the usage of sewage sludge stabilized with biomass ash enhances the fertility of the soil.

Keywords: Soil Stabilization; Sewage Sludge; Biomass Ash; Soil Salinization

1. Introduction

In the last two decades, the Productive agricultural lands have been deteriorated continuously due to increase in salinization of soil. Soil salinity is the main reason or the rupture of the land after erosion. Due to the increasing content of sodium in soils, the soil is becoming saline-sodic soil and this further leads to higher pH value of soil. Nowadays the attractive forces in the soil are decreasing due to this increase in salinity and sodium content in the soil. Although this problem is increasing, it can be countered using several measures out of which one is the treatment of soil with stabilized sewage sludge. The reclamation of soil using stabilized sewage sludge or leaching water can remove the excess soluble salts and sodium content from the soil. In most of the Asian and European countries, the municipal sewage sludge is used after its stabilization with some geopolymer or stabilizing agent. The stabilizers can be aerobic or anaerobic depending upon its materialistic characteristics. In recent times the usage of aerobic stabilizing agents is preferred over anaerobic stabilizing agents as the usage of anaerobic demands conditioning under controlled temperatures.

The process of management and safe disposal of sewage sludge is a major concern for modern society. As we know the process of water treatment involves the primary treatment, secondary treatment and tertiary treatment, and the residue obtained after tertiary treatment has to be disposed-off, so at that point of concern, usage of this residue for performing several wide-ranging functions can be a solution. The progression of municipal sewage sludge stabilization

* Corresponding author: Anhar Yousuf Wani, Mobile: +91 6006036003, E-mail: anharwani5@gmail.com

is necessary to reduce the problems involving odor, and presence of pathogens. In several east European countries, approximately 10000 to 20000 tons of this municipal sewage sludge is used as an additive to agricultural purposes. It can easily be used for the stabilization of soil to enhance certain deterministic properties such as soil structure, soil fertility and yield production. With time the concentration of this sewage sludge is also increasing so usage of this should be implemented in other Asian countries also. The common methods of treatment of this sewage sludge are the incarnation of this residue that will reduce the volume significantly. The sewage sludge can also be termed as the concentrated bio-active residue of mostly organic clay-sized particle derived from the waste-water treatment process. In various countries, there is an almost complete dependence on landfilling since the spreading of sewage sludge (with toxic constituents) is banned and incarnation may not be an option. Sewage sludge generated have high moisture content else high presence of heavy metals which can not be disposed of directly into the land due to threat of environmental contamination. Waste recycling and waste disposal are one of the biggest challenges that are faced in our times. The sewage sludge that is a solid- water mixture, is the main by-product of industries. Sludge comprises 2-15% oven-dried solids and shows characteristics of slurry. The focus of this research is on the improvement of mechanical and geotechnical properties (California bearing ratio (CBR)), Direct shear test, compaction, consolidation, compression of sewage sludge, through the chemical stabilization by using Biomass Ash. Biomass ash being an in-expensive industrial by- product. On the other hand, ash is also a waste material generated during the combustion of biomass and disposal of the same is posing an environmental hazard. So, it has become crucial to reduce the storage of these toxic materials by its bulk utilization. The Table 1 is showing the typical range of different metal in the sewage sludge and soil.

Table 1 Critical levels of heavy metals in sewage sludge and soil

Element	Sewage sludge (mg/kg of dry weight)	Soil (mg/kg of dry weight)
Cu	1100–1850	60–150
Ni	400–500	40–85
Pb	850–1300	60–400
Zn	2600–4100	160–310
Hg	20–30	2–2.5

2. Literature review

Cerne et al., [1] published a study based upon the effect of several types of municipal sewage sludge over the deterministic properties of soil. This study associated with the usage of stabilized municipal sludge at different proportions also. The traces of several metals and alloys were determined using gamma-ray spectrometry. It was concluded that the concentration of chromium, nickel and mercury in anaerobic sewage was more as than that of aerobic sewage which shows that the aerobic sludge needs excessive stabilization for its usage concerning practical concerns.

Falayi [2] investigated the alkaline leaching of phosphorous from sewage sludge using sodium hydroxide and potassium hydroxide. The sewage sludge was first stabilized via a process of geo polymerization. It was noted that the leaching of phosphorous using potassium hydroxide was exceptionally more as in the case of sodium hydroxide. The prepared geopolymer was cured at 100^{o} C for 5 Days yielding it to attain the desired strength of 14.2 MPA. The obtained geo polymer cope up with minimum statutory requirements for leaching of sewage sludge and hence can be used to attain futuristic safetyand disposal.

Hermassi et al. [3] utilized the organic matter present in the municipal sewage sludge for the production of bioenergy. This not only promotes the usage of bioenergy from waste organic matter but also meets the needs of forthcoming generation. In this study the effect of liquor suspended solids present in secondary sludge on the electricity generation has been investigated. For obtaining certain results, cathode and anodic electricity generation tubes along with respective cells were used for. It was observed that the process in the cathode chamber was more efficient as paralleled to the process in an anodic chamber so concerning to the above point maximum power generation and maximum efficiency must be associated with cathode chamber.

Murray et al. [4] studied the effect of biosolids stabilization over the distribution of the antibiotic-resistant genes in soil. The biosolids obtained from the stabilized sewage sludge were first heat-treated and then stabilized using LYSTEK process. The class-A biosolids were only heat treated whereas the class-B were stabilized only using LYSTEK process. It was concluded that the land application of class-A biosolids will entrain fewer bacteria and genes as compared to class-B biosolids. It wasalso concluded that, with the usage of biosolids, the overall vegetation or agricultural efficiency has also been increased to a larger extent.

Sahin et al. [5] performed their research work for improving the hazardous nature of soil salinization. Generally, soil salinization was stabilized using sewage sludge and recycled wastewater. Both these terminologies are associated with environmental waste whose dumping is very much difficult from normal impacts. In this study, experiments were performed up to a depth of 15cm to determine the effect of stabilized sewage sludge over saline soil. It was concluded that the sewage sludge and recycled wastewater with a moderate quantity of saline and sodic particles can easily be used for the leaching process of saline-sodic soil. It was also concluded that the stabilization process leads to considerable improvement in the soil conductivity also.

Samara et al. [6] studied the impact of stabilization of sewage sludge using steel slag and concerning that the effect over several exocentric properties of soil wasconcluded. Dewatered sewage sludge with steel slag and 3 different types of soils were used to experiment. It was observed that the usage of sewage sludge for the stabilization of soil can implement to a required extent only. It was also observed that the lesser will be theconcentration of metallic ions in the sludge more will be the stability of the soil. Certain conclusions were made which reflects that the sewage sludge stabilized with steel slag can be used to enhance the fertility of the soil.

Visigalli et al. [7] used the pressure-driven technique for the dewatering of municipal sewage sludge. This pressure-driven technique was experimented using a lab device. Overall wastewater from 4 different areas wassupplied for the pressure-driven dewatering process and it was observed that this process leads to dewater the sludge samples to a dry solid content of approximately 15% to 30% which was far better than the normal dewatering process.it was concluded that this technique of stabilizing the sewage sludge can decrease the stabilization cast up to 35% annually.

Zhong et al. [8] studied the usage of bio-electrochemically-assisted VERMIFILTER system for the stabilization of municipal sewage sludge obtained after secondary sewage treatment. The above said treatment improved the sludge stabilization with a higher biological oxygen demand and chemical oxygen demand.it was observed that the bacterial content prepared using above said the system was found to be richer and higher in terms of diversity as compared normal stabilization, which concluded that the bio electro genesis accelerated the anaerobic compositing maturity and in a broader perspective the bio-electro-chemical process enhances the stabilization of sewage sludge with synchronous electricity generation.

3. Material and methods

For the current research, the sewage sludge has been collected from the Delhi Jal Board, New Delhi, India. Before performing any test on the sewage sludge, it is dried in the oven at 105 ^{0}C to 110 ^{0}C.

4. Results and discussion

4.1. Sewage Sludge

In context with the present research work dewatered sewage sludge was taken from the water treatment plant situated at New Delhi, India. This dewatered sewage has pH of 9.60 and the electrical conductivity was found to be 32.00 (ds m^{-1}) approximately. According to several researchers, the municipal sewage sludge can also be dewatered using a hydrostatic process with pumping action which will reduce the speed of dewatering and increases the efficiency of the residue obtained. Various physiochemical properties of dewatered sludge are presented in the Table 2.

4.2. Biomass Ash

Biomass ash used for the research work was generally derived from a combustion boiler situated in Haryana, India. Previously this bi-product was used by various researchers for enhancing the properties of soil as well as concrete. Generally, biomass ash can be derived from the combustion of various bioproducts such as wood, rice husk, coconuts etc. all the residues of these bioproducts when combusted they lead to the formation of biomass ash. The chemical composition of biomass ash used for the present study is shown in Table 3.

Table 2 Chemical and physical properties of stabilized sewage sludge

Parameter	**Percentage in Sewage Sludge**
Organic matter (%)	0.53
Clay (%)	42.4
Silt (%)	28.9
Sand (%)	31.7
Wet aggregate stability (%)	3.25
pH	9.60
Electrical conductivity	3.20
CaCO3 (%)	17.5
Cation Exchange Capacity (cmol kg^{-1})	35.1
Total N (%)	0.073
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Table 3 Chemical composition of Biomass Ash (Wt. %)

Chemical	**Percentage in Biomass Ash**
Silica	15.78 %
Alumina	19.70 %
Iron oxide	8.21 %
Calcium oxide	22.76 %
Magnesium oxide	9.93 %
Potassium oxide	8.31 %
Sodium oxide	1.19 %
Zinc oxide	0.09 %
Manganese oxide	0.07 %
Titanium oxide	0.76 %
Sulphate oxide	2.14 %
Phosphate	0.96 %

4.3. Soil Sample

Soil surface samples were collected from several locations to determine the effects of municipal sewage sludge stabilized with biomass ash over it. Overall soil sample after the process of oven drying was passed through 2mm sieve. The Particle size of soil was determined by Hydrometer analysis process. Soil pH and EC values were measured in saturated paste extracts. The pH was read with a pH-meter and salinity was determined by measuring with an EC-meter. Organic matter concentration in the soil was determined by the Smith-Weldon method, $CaCO_3$ with a Scheibler Calciminer and total N by the Kjeldahl method, Na and K were extracted with ammonium acetate solution using a flame photometer. Various physical and chemical properties of soil sample collected are shown in Table 4.

Table 4 Chemical and physical properties of saline-sodic soil

Parameter	Percentage in Soil
pH	7.09
Electrical conductivity	2.07
CaCO3 (%)	1.57
Cation Exchange Capacity (cmol kg^{-1})	61.6
Total N (%)	4.65
Organic matter (%)	45.0

4.4. Statistical Analysis

All the measured data were then subjected to statistical analysis using Statistical package SPSS Software with the application of which analysis of variance (ANOVA) was executed.The main purpose of statistical analysis was to test the required hypothesis that different stabilization procedures affect the physicochemical properties of municipal sewage sludge stabilized using biomass ash. Afterwards, Analysis of variance was used as an application to predict the effect of municipal sewage sludge stabilized with biomass ash over the deterministic soil parameters.

4.5. Municipal Sewage Sludge Stabilization with Biomass Ash

Table 5 Quantity of Biomass Ash and Sewage Sludge

Mix	Sewage Sludge (%)	Biomass Ash (%)
M-1	90	10
M-2	80	20
M-3	70	30

Table 6 Sewage sludge stabilization results

Parameter	Results for M1	Results for M2	Results For M3
pH	8.56	10.52	12.95
Moisture Content (g Kg^{-1})	43.64	55.39	65.32
Electrical Conductivity (dSm^{-1})	2.15	2.76	3.14
Equivalent Calcium Carbonate (g Kg^{-1})	193	218	260
Nitrogen Content (%)	1.97	2.82	3.71

During the initial stage of the research work, a preliminary experiment was conducted to determine the optimum percentage of biomass ash to be used for achieving maximum efficiency. Biomass ash was used at different proportions that are at 10%, 20% and 30% to acquire maximum output from the stabilized sewage sludge. Different proportions used areshown in the Table 5 and 6. The whole experiment was left for equilibration outdoors for a month. After this periodic mixing samples of different proportions were collected andtested for pH and pathogens.

4.6. Effect of Stabilized Sludge over Chemical Properties of Soil

Based on the test results, soil pH was affected significantly with its treatment with stabilized sludge. As expected, the pH and electrical conductivity increases significantly with the addition of stabilized sludge in it. The rate of increase in pH depends upon several factors out of which one can be pH of the soil before treatment, the concentration of calcium carbonate in it and buffering capacities of the soil. The effect of stabilized sludge on several further properties of soil has been tabulated in Table 7.

Table 7 Effect of Stabilized Sludge over Chemical Properties of Soil

Parameter	Results After Treatment
pH	8.49
Moisture Content (g Kg^{-1})	57.62
Electrical Conductivity (dSm^{-1})	2.84
Equivalent Calcium Carbonate (g Kg^{-1})	274
Nitrogen Content (%)	3.19

4.7. Effect of Stabilized Sludge over Soil Macronutrients

As far as the risk of groundwater pollution is concerned, the percentages of macronutrients obtained after the treatment of soil with stabilized sewage don't exceed the hazardous limits. At the end of the biological treatment. It was observed (Table 8) that the percentage of NO_3-Nincreases significantly with the addition of stabilized sludge and the same results were observed for certain other macronutrients such as methane, nitrogen content and phosphorous.

Table 8 Effect of Stabilized Sludge over Soil Macronutrients

Available Macronutrients After Treatment	Results After Treatment
NO3-N (mg kg^{-1})	41.35
NH4-N (mg kg^{-1})	36.88
P (mg kg^{-1})	31.62

4.8. Effect of Stabilized Sludge over Soil Micronutrients

Various unexpected trends in the content of several micronutrients were observed, with the biological treatment of soil with stabilized sludge. In all cases of the metal micronutrients, their increase was attributed mainly to the nutrients added to the soils in the form of the stabilized sludge, since it contained considerable amounts of those elements. From the results, it was found that the maximum increase was observed in the values of Copper (Cu), Zinc (Zn) and Iron (Fe). All further changes in the content of certain micronutrients are shown in Table 9.

Table 9 Effect of Stabilized Sludge over Soil heavy metal content

Available Micronutrients After Treatment	Results After Treatment
Cu (mg kg^{-1})	2.66
Zn (mg kg^{-1})	5.39
Fe (mg kg^{-1})	28.33
Mn (mg kg^{-1})	29.42
B (mg kg^{-1})	0.75

5. Conclusion

In the present research work, sewage sludge stabilized with biomass ash was used to enhance the acquisitive properties of soil. This study assesses the prospective usage of sewage sludge as soil alteration by considering their nutritional status as well as physicochemical characteristics. Depending upon the experimental work and their respective results, the following conclusions are drawn:

- The results of the current study show that the optimum proportion (20%) of usage of biomass ash for the stabilization of municipal sewage sludge lies in between the maximum and minimum replacement values. Although the maximum pH was attained at extreme percentage replacement of biomass ash nevertheless from agricultural as well as ecological perceptive it can be hazardous.
- Considering the results obtained for certain chemical properties of concrete, it was observed that with the addition of stabilized sewage in soil, the Phi and electrical conductivity increases significantly which ensures the increase in the fertility of the soil. Considering the same results for infertile and weak soil, this treatment must be implemented
- Concerning the results obtained in the content of macronutrients, it can be depictedthat this increase in the content of macronutrients tends to increase with the further addition of stabilized sewage and this further increases the materialistic properties of soil. So therefore, with further increase in macronutrients, sewage sludge can be used in place of certain harmful fertilizers and pesticides to fulfil several agricultural purposes.
- Furthermore, it was noted that the concentration of heavy metals in treated soil doesnot surpass the hazardous limits as per the American Legislature, concerning the agriculture usage of sewage sludge.

Compliance with ethical standards

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Disclosure of conflict of interest

There is not any conflict of interest among any authors.

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