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# Physio-chemical characterization of sewage sludge generated from sewage treatment plant at Varanasi, in relation to nutrients and heavy metals for agriculture use

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## ABSTRACT

Large amount of sewage sludge is generated during waste water treatment at sewage treatment plant (STP), as a result of the sedimentation and suspension of particles. The safe disposal and management of this concentrated sewage sludge posesa major challenge for town and city municipal corporations. However, this could also be used in agriculture as an input to partially replace recommended doses of fertiliser. Thus, the current study was conducted to investigate the physio-chemical and biological characteristics of sewage sludge (SS) and its potential application in agricultural fields as an organic manure. Sewage sludge samples were collected from sewage treatment plant (STP) at *Bhagwanpur*, Varanasi, India and sieved in 2 mm mesh before being analysed for various physical and chemical characteristics. The processed sewage sludge possessed both major [total nitrogen (1.76 %), total phosphorous (1.29%), total potassium (1.15%)] and micro nutrients (Fe, Mn, Zn and Cu) and significant amount of organic carbon (8.67 %). However, this sewage sludge was also containing considerable amount of heavy metals like Cadmium (7.3 mg $kg^{-1}$), chromium (49.2 mg $kg^{-1}$), nickel (total 27.43 mg $kg^{-1}$), and lead (39.53 mg $kg^{-1}$), which were reported to be harmful to human beings, but these were lower than threshold limit recommended by Council of the European Communities, 1988 for agricultural use. Further, Bulk density and water holding capacity was 1.18 g $cm^{-3}$ and 54.5 % respectively. With respect to microfauna, fungi were found more dominating than actinomycetes and bacteria in this sewage sludge. Therefore,considering use of this sewage sludge for agriculture may decrease the use of chemical fertilisers and make it more sustainable. However, in order to increase soil health without posing an environmental risk, sewage sludge must be carefully evaluated before being applied to soil especially for heavy metals and other hazardous pollutants.

***Key words:*** *Sewage sludge, Heavy metals, Cadmium, Chromium, Nickel and lead.*

## Introduction

Increase in population and urbanisation has led to excess production of sewage and whose management and safe disposal is a contemporary challenge and needs more investigation. sewage waste water causes problems when it combines with water sources and posing negative impact on water quality and aquatic life (Latare *et al.,* 2014). Sewage treatment plants (STPs) are not only to treat household wastewater, but also gives primary and secondary treatment to wastewater which is already treated with activated sludge. In India,the total waste water generation in class I and class II municipalities were 35,558 and 2,696 million litre per day (MLD) (Kaur *et al*., 2012). Particularly, in Varanasi, 230.17 MLD sewage effluent is generated daily (CPCB, 2005). It has been predicted that by 2050, about 132 billion litres per day of wastewaters would be generated in India (Bhardwaj, 2005). Therefore, STPs plays a crucial role in decreasing water and soil pollution. If this waste water is not treated, it enters to water bodies and ground water etc. and contaminates the whole system of water and soil, resulting in degradation of soil and water quality and disruption of the aquatic system (Latare *et al.,* 2014).

Sewage sludge (SS) is a semi-solid residual material produced by sewage treatment plants as a by-product whichpossess greater amounts nutrients, pollutants and biological activity (Kumar and Chopra, 2016a). The solid wastes are separated as sewage sludge when the wastewater enters the treatment plants and undergoes multiple mechanical, biological, and chemical processes (Demirbas *et al.,* 2017). Sedimentation, precipitation, extraction, membrane filtration, adsorption on activated carbon, ion-exchange, oxidation, biodegradation, and electrochemical treatment are some of the various methods used for wastewater treatment (Sher *et al*., 2013). To remove toxic micropollutants and other suspended particles from waste water, advanced procedures such as electro-coagulation and electro-flocculation can be used (Sher *et al*., 2020a).

Further, following excessive sewage production, the number of STPs for wastewater treatment and recycling has also been increased in India. Consequently, the volume of (SS) has risen significantly (Demirbas, 2003; Shao *et al.,* 2015) and appropriate management of this large volume of sewage generated has become a crucial challenge to address.A large portion of the SS generated across the world is either utilised for agriculture or burnt, or left as land filling (Vochozka and Maroušková, 2017). Many studies have reported that SS possesshigh nutrient and organic matter, making it an effective fertiliser for improving soil fertility and crop output (Smith, 2009; Cieslik *et al*., 2015). However, presence of heavy metals (such as Cd, Cr, Cu, Ni, As, Pb, and Zn) and other hazardous pollutants, hinders and demotivates the concept of utilising sewage sludge in agriculture (Dai *et al.,* 2006; Singh and Agrawal, 2007). Nevertheless, physio-chemical characterisation of the SS for various macro and micro nutrients and heavy metals helps in making decision to use available SS for agricultural use (Jatav *et al.* 2021). Further, it has found that if the SS dose surpasses 45 tonnes per hectare, there is a risk of heavy metal build-up (Latare *et al.,* 2014). Therefore, the present study aims at physio-chemical and biological characterisation of locally available SS generated at STP, Bhagwanpur (Varanasi), India with respect to macro and micro nutrients and heavy metals, along with biological activity.

This study found that sewage sludge from STP, Bhagwanpur, Varanasi possess higher amount N, P, K, Fe, Zn, Cu and Mn, which is necessary for plant growth and development. However, it also possesses significant amount of heavy metals such as Cd, Cr, Ni and Pb, but they were below the threshold limit recommended by the Council of the European Communities, 1988 for agricultural use. Unfortunately, we couldn't able to measure other heavy metals and pollutants.

## Materials and Methods

### Collection and processing of Sewage sludge

Sewage sludge (SS) was collected in summer, 2019 from Bhagwanpur STP (25° 19' 18.0624'' N and 82° 59' 14.2404'' E) located in south of Varanasi city, Uttar Pradesh, India (Fig. 1). Portion of the collected SS was separated by precise sampling and stored at 10-20 °C in plastic zip lock bags formicrobiological assays. For physio-chemical analysis, samples were dried in oven at 105 °C for 6 hours and were powdered using pestle and mortar and sieved in 2 mm sieve to remove the physical contaminants like plant parts, stones, plastics etc. (Fig. 2). Following, the fine well mixed sample were used for physio-chemical characterisation including micro-nutrients and heavy metals estimation.

### Physio-chemical characterisation of sewage sludge, macro and micro nutrient analysis

Different physical, chemical, and biological aspects of the collected SS were examined further. The bulk density of sewage sludge was determined according to Piper, 1966. The water holding capacity of sludge was determined using keen box according to

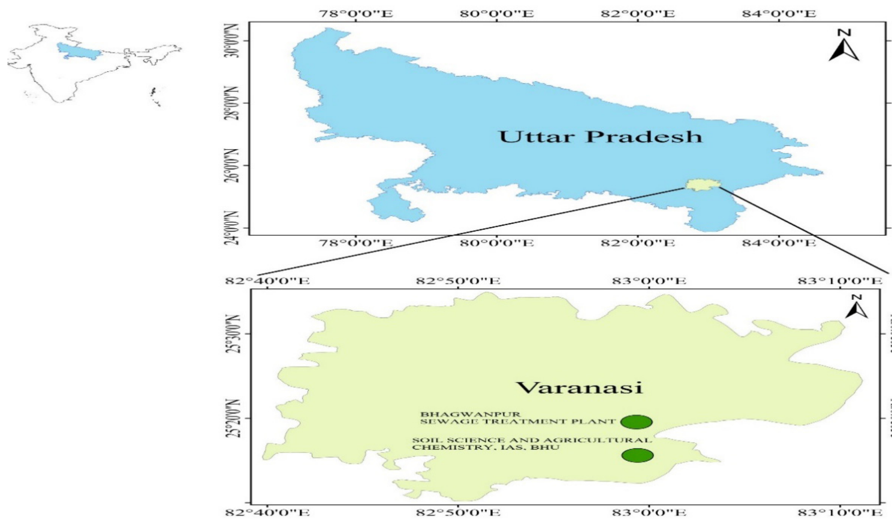


**Fig. 1.** Location of sewage treatment plant (STP), Bhagwanpur, Varanasi, India-221005.

method described in Piper, 1966.

The moisture percentage in sewage sludge was measured using the moisture box formula given below.

$W=M_2-M_3/M_3-M_1$,

Where W= Moisture Percentage,

M1= Mass of empty container with lid

M2= Mass of the container with wet soil and lid

M3= Mass of the container with dry soil and lid.

The pH and EC of SS were determined in 1:2.5 soil: water suspension according to method given by Jackson, 1973, and Organic carbon was estimated according to Walkley and Black, 1934. Further, Cation exchange capacity was determined by distillation method, andavailable nitrogen (N) was estimated by 0.32% alkaline $KMnO_4$ method (Subbiah and Asija, 1956). The available phosphorus (P) content was determined by the ascorbic acid method given by Olsen *et al.*, 1965. The available potassium (K) content was determined by the 1N neutral ammonium acetate method (Hanway and Heidel, 1952). The aqua regia digestion mixture was used to determine total micronutrients and heavy metals. Soil samples are digested on a heated plate with a 3:1 combination of HCl and $HNO_3$ in the traditional aqua regia digestion technique (Nieuwenhuize *et al.*,

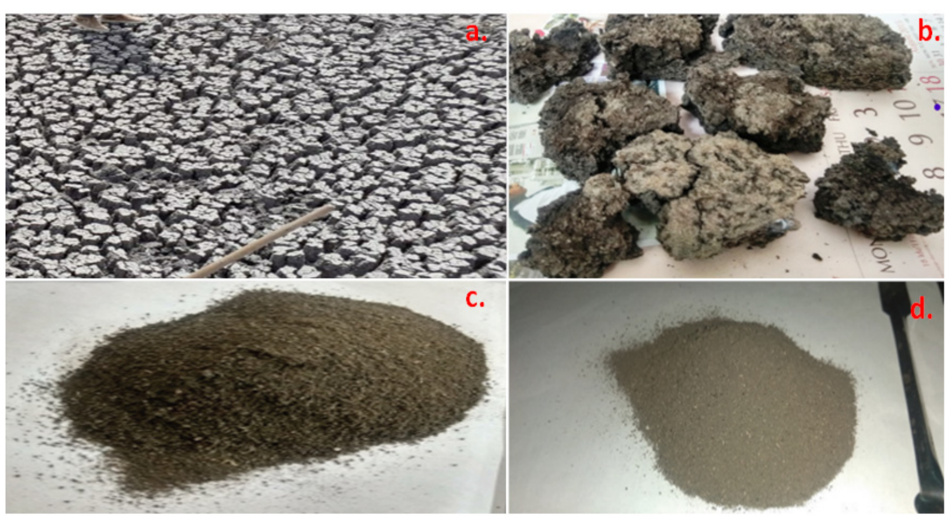


**Fig. 2**. Sewage sludge (SS) from Bhagwanpur STP, Varanasi. a. SSin solid form after waste water treatment. b. SSbefore processing, c.SS obtained in powder form after grinding, d. fine powder of SSafter sieving in 2mm sieve.

1991). By using anatomic absorption spectrophotometer (Agilent FS-240), the DTPA extractable (available) micronutrients (Fe, Cu, Mn, and Zn) and heavy metals (Cd, Cr, Ni, and Pb) were determined according to Lindsay and Norvell, 1978. The number of bacteria, fungi and actinomycetes was determined by serial dilution and plating technique using asparagine-mannitol agar medium (Thornton, 1922), rose bengal streptomycin agar medium (Martin, 1950) and Ken Knight and Munaier's medium (Chhonkar *et al.,* 2002).

## Results and Discussion

### Physical Properties of sewage sludge

The bulk density, water holding capacity (WHC) and moisture content of the SS were 1.18 mg m$^{-3}$, 54.45%, and 6.78% respectively (Table 1).

**Table 1.** Physical Properties (Bulk density, water holding capacity and moisture content)of Sewage sludge of Bhagwanpur sewage treatment plant, Varanasi. Values represents mean ± SE.

| Parameters | Sewage Sludge |
|---|---|
| Bulk Density | 1.18±0.06 |
| Water holding Capacity (%) | 54.45±4.05 |
| Moisture (%) | 6.78±0.29 |

The low bulk density could be due to higher organic matterand microbial gum synthesis (Kumar *et al.,* 2011). The higher WHC in the SS, could be due to lower BD, because WHC is generally depended on the bulk density of the material (Latare *et al.,* 2014; Delibacak *et al.,* 2020). Further, the moisture content in SSactivates different microbial activity in the soil. The lower BD and higher WHC of the SS could makes it angood amendment to improve the soil bulk density. Many studies have found that application ofSScould improve the soil's physical properties.

### Chemical properties and nutrients content

The SS was also further studied for the chemical properties and were given in Table 2. The pH of SS was 6.6 (slightly acidic), EC:3.17 dS m$^{-1}$, organic carbon: 8.67 % and cation exchange capacity :82.0 cmol (p$^{+}$) kg$^{-1}$.

Macronutrient analysis (N,P, and K) showed that, the collected SS samples had available N: 147.28, P: 67.15 and K: 170.03 mg kg$^{-1}$, respectively. Whereas, the total N, P and K were 1.76, 1.29 and 1.15% respectively (Table 2).

The SS is also analysed for DTPA extractable available elements which can be available for plant growth if applied in the soil represented in Table 2 and Fig. 3. The DTPA extractable iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn) contents of SS were 83.47, 29.90, 27.45 and 34.77 mg kg$^{-1}$ respectively. The DTPA extractable of heavy metals Cd, Cr, Ni and Pb in SS were 3.44, 8.86, 6.91 and 10.22 mg kg$^{-1}$ respectively. Whereas the total content of Fe, Cu, Mn and Zn in SS were 490.27, 240.63, 246.08, 184.27 mg kg$^{-1}$and total content of heavy metalsCd, Cr, Ni and Pb in SSwere 7.3 mg kg$^{-1}$, 49.20mg kg$^{-1}$, 27.43 mg kg$^{-1}$ and 39.53 mg kg$^{-1}$, respectively (Table 2 and Fig. 4). The heavy metals content which is critically important to consider SS for the safe usage in agriculture. According to Council of the European Communities, (1986), the permissible limit for potentially toxic elements such as Zn, Cu, Cd, Pb, Ni and Cr in SSfor agricultural soils are 2500-4000 mg kg$^{-1}$, 1000-1750 mg kg$^{-1}$, 20-40 mg kg$^{-1}$, 750-1250 mg kg$^{-1}$, 300-400 mg kg$^{-1}$ and 750-1200 mg kg$^{-1}$respectively. In the present study all the heavy metals measured in SS were lesser than the threshold limit suggested by Council of the European Communities, (1986) for use in agriculture (Council of European Communities, 1986). Therefore, utilising this SS in agriculture may not pose greater threat to soil and aquatic ecosystem, however further analysis of other trace elements and pollutants like arsenic, mercury etc. need to be analysed before considering it for agricultural use. Moreover, this SS has good amount of nutrients and organic matter, which could minimise the chemical fertiliser application, but continuous use of SSmay lead toheavy metals build of in the soil (Delibacak *et al.,* 2020)

### Microbial Properties

The study found that SS has a greater number of

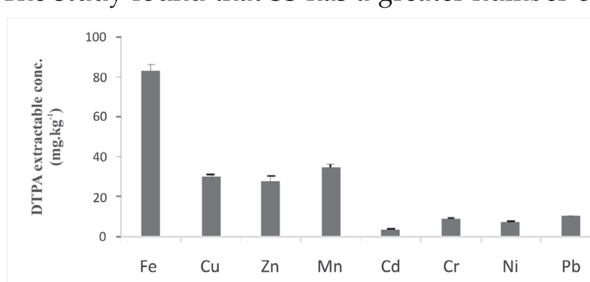


**Fig. 3**. DTPA extractable trace elements content (mg kg$^{-1}$) in sewage sludge of sewage treatment plant, Bhagwanpur, Varanasi

microfauna bacteria, fungi and actinomycetes. The bacterial content was 40.55×$10^{-6}$cfu $g^{-1}$ of soil, fungi : 27×$10^{-4}$cfu $g^{-1}$ of soil and actinomycetes were 39.20 × $10^{-5}$cfu $g^{-1}$ of soil respectively (Table 3). Therefore, with good amount of microbial activity, this SS could improve soil biological activity and decomposition rate. However further study on determining type of microfauna (beneficial and harmful) present in SS is necessary to know its biological and microbial value.

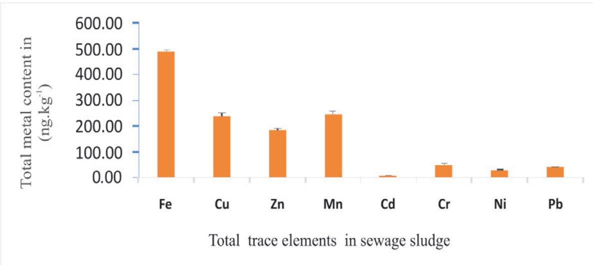


**Fig. 4.** Total trace element content (mg $kg^{-1}$) in sewage sludge of sewage treatment plant, Bhagwanpur, Varanasi

**Table 3.** Microbial properties of sewage sludge of Bhagwanpur sewage treatment plant, Varanasi Values represents mean ± SE

| Parameters | Unit | Sewage sludge |
|---|---|---|
| Bacteria | ($10^{-6}$cfu $g^{-1}$ soil) | 40.55±3.51 |
| Fungi | ($10^{-4}$cfu $g^{-1}$ soil) | 27.44±2.89 |
| Actinomycetes | ($10^{-5}$cfu $g^{-1}$ soil) | 39.81±2.61 |

## Conclusion

The management and safe disposal of SS produced in India is a contemporary issue and requires greater

**Table 2.** Chemical and nutrient properties of sewage sludge of Bhagwanpur sewage treatment plant, Varanasi. Values represents mean ± SE.

| Parameters | Units | In SS | Limit values*(mg/ kg) |
|---|---|---|---|
| pH (soil: water, 1:2.5) | (pH Units) | 6.6±0.15 | - |
| EC | (dS $m^{-1}$) | 3.17±0.1 | - |
| Organic Carbon | (%) | 8.67±0.31 | - |
| CEC | cmol($p^+$)$kg^{-1}$. | 82±6.56 | - |
| Available content | | | |
| Nitrogen | (mg $kg^{-1}$) | 147.28±3.99 | - |
| Phosphorous | (mg $kg^{-1}$) | 67.15±4.13 | - |
| Potassium | (mg $kg^{-1}$) | 170.03±7.09 | - |
| Total Content | (%) | | - |
| Nitrogen | (%) | 1.76±0.08 | - |
| Phosphorous | (%) | 1.29±0.04 | - |
| Potassium | (%) | 1.15±0.03 | - |
| DTPA extractable | | | |
| Iron | (mg $kg^{-1}$) | 83.47±2.95 | - |
| Cupper | (mg $kg^{-1}$) | 29.9±1.37 | - |
| Zinc | (mg $kg^{-1}$) | 27.45±2.95 | - |
| Manganese | (mg $kg^{-1}$) | 34.77±1.62 | - |
| Cadmium | (mg $kg^{-1}$) | 3.44±0.15 | - |
| Chromium | (mg $kg^{-1}$) | 8.86±0.3 | - |
| Nickel | (mg $kg^{-1}$) | 6.91±0.6 | - |
| Lead | (mg $kg^{-1}$) | 10.22±0.3 | - |
| Total Content | | | |
| Iron | (mg $kg^{-1}$) | 490.27±5.02 | - |
| Cupper | (mg $kg^{-1}$) | 240.63±10.45 | 1000-1750 |
| Zinc | (mg $kg^{-1}$) | 184.27±7.77 | 2500-4000 |
| Manganese | (mg $kg^{-1}$) | 246.08±12.48 | |
| Cadmium | (mg $kg^{-1}$) | 7.3±0.5 | 20-40 |
| Chromium | (mg $kg^{-1}$) | 49.2±7.22 | 750-1200 |
| Nickel | (mg $kg^{-1}$) | 27.43±3.56 | 300-400 |
| Lead | (mg $kg^{-1}$) | 39.53±4.51 | 750-1250 |

attention and investigation to find possible approaches to minimise it negative impact on soil and aquatic eco-system. One of the possible optionis to use this nutrient enriched SS as an input for crop production. However, sewage sludge also possess various hazardous pollutants and impermissible level of metals. Thus prior-characterisation of SS intended to use in crop production is an important pre-requisite. In the present study the collected SS sample contained good amount macro and micro nutrients such as N, P, K, Fe, Zn, Mn and Cu, which are essential for crop growth and development. Further heavy metals such as Cd, Cr, Ni and Pb were lower than the threshold level recommended by EU in 1988 for agricultural use. However, the effect of the SS on soil, ground water, and plants needs to be evaluated before it is used on agriculture as an organic fertilizer. This information will be useful for determining suitable rate of application of SS and for investigating pollutant risks that may be associated with the use of SS.

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