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Changes in macronutrient content in sludge as affected by sources and seasons

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ABSTRACT

An attempt has been made in assessing variability of macronutrient content in sludge as affected by sources and seasons at Indian Agricultural Research Institute, New Delhi. For this purpose, sludge samples were collected from eight different sewage treatment plants (STPs) located in and around Delhi (CP: Coronation Pillar, DG: Delhi Gate Nalla, KSP: Keshopur, NIL: Narella, NLT: Nilothi, OKH: Okhla, PPK: Pappankallan and RTL: Rithala) in 2018-19. Results indicated that sludge samples collected from different sources were acidic in nature and varied from 6.34 to 6.65 with mean of 6.44, and electrical conductivity of sludge ranged from 2.95 to 5.74 dS/m with mean of 4.17 dS/m. Sludge generated at different (STPs) of Delhi were rich in total carbon (TC) (10.5–35.1%) and macronutrients, viz. nitrogen (N) (1.21–2.64%) and phosphorus (P) (0.95–1.84%); but the potassium (K) content (0.16–0.32%) was much lower. The corresponding mean values of TC, N, P and K in sludge samples across the sources and seasons were 20.4, 1.98, 1.35 and 0.24%, respectively. Seasonal occurrence pattern of macronutrient, i.e. N, P, and K were higher in sludge collected during summer followed by winter and rainy season. Sludge can be a potential source of plant nutrients, particularly in the face of rise in the price of NPK fertilizers.

Key words: Chemical properties, Macronutrients, Organic carbon, Seasons, Sludge

Sewage sludge (SS) is a heterogeneous mixture of undigested organics such as cellulose, plant residues, oil, or fecal material and inorganic materials. In India, total sewage generated from urban areas was estimated as 62000 million litres per day (MLD), while the capacity of treatment plant across India is only 23277 MLD, or 37% of total sewage generated (Central Pollution Control Board 2016). In Delhi, total 36 sewage treatment plants (STPs) are operational at 20 locations with total treatment capacity of 607 million gallon per day (MGD). Total sewage sludge produced from different STPs is approximately 250–300 metric tons per day (Delhi Jal Board 2017). Sludge is composed of high concentrations of nutritional compounds and elements, viz. organic matter (OM), macronutrients, like nitrogen, phosphorus, and potassium which are required for growth and development of plants (Sanchez *et al.* 2017, Turek *et al.* 2019). Sewage sludge produced from STPs had acidic to alkaline in reaction, high electrical conductance, approximately 23–50% of organic matter, 1.86–3.16% of nitrogen (N), 1.53–2.42% of phosphorus (P) and 0.97–1.64% of potassium (K) (Singh and Agrawal 2008, Saha *et al*. 2017, Saha *et al.* 2018).

Use of sewage sludge in agriculture is an effective way of supplementation of organic matter to improve crop productivity, soil health including preventing erosion (Mahapatra *et al*. 2013, Alvarenga *et al.* 2015, Eid *et al.* 2018, Turek *et al.* 2019), and enhances biological activities (Saha *et al.* 2017). Addition of sludge was reported to enhance the yield of various important crops, like rice, wheat, maize, sorghum, broad bean, cucumber, palak and others (Singh and Agrawal 2010b, Golui *et al.* 2014, Sharma *et al.* 2017, Eid *et al.* 2019). Nowadays, farmers in peri-urban areas used sludge in agriculture production system as organic manure as well as source of plant nutrients. Characterization of sludge for chemical composition as affected by season is necessary for judicious use in crop production with the ultimate aim of curtailing the use of costly chemical fertilizers. With this background, present investigation was carried out to assess the effect of source (STPs) and season on chemical properties and macronutrient content in sludges collected from Delhi.

MATERIALS AND METHODS

Collection and preparation of sludge samples: Sludge samples were collected from the eight different sewage

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treatment plants (STPs) of Delhi, viz. Coronation Pillar, Delhi Gate, Keshopur, Narella, Nilothi, Okhla, Pappankallan and Rithala. The sludge samples were collected in summer (June 2018), rainy (August 2018) and winter season (January 2019). Annual rainfall of Delhi varies from 337 mm to 887 mm. These sludge samples were dried, ground, passed through 2 mm sieve and used for chemical analysis. Soil chemical analysis was carried out in the Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, New Delhi.

Chemical analysis of sludge: The *p*H and electrical conductivity of sludge samples were determined in sludge using sludge to water ratio of 1: 5. Total carbon (TC) and nitrogen (N) were analyzed by dry combustion method (Nelson and Sommers 1982) in CHNS analyzer (Euro Vector make, Euro EA3000 model). Sludge samples were digested with di-acid mixture of nitric acid and perchloric acid (HNO_3: $HClO_4$ :: 9 : 4). The P and K content in digest was determined by ascorbic acid method (Watanabe and Olsen 1965) and flame photometer (Jackson 1973), respectively.

Statistical analysis: An analysis of variance (ANOVA) method was followed to assess the effect of source (treatment plants) and season on variation in chemical properties and macronutrient content in sludge (Snedecor and Cochran 1967).

RESULTS AND DISCUSSION

pH and EC of sludge: The pH of sludge samples varied from 5.89–6.56, 6.34–6.59 and 6.46–7.01 in summer, rainy and winter seasons, respectively with the corresponding mean value of 6.16, 6.48 and 6.68 (Table 1). On an average, the highest value of *p*H was recorded in sludge sample collected from Narella and lowest was observed in Coronation Pillar. The highest mean value of pH was recorded in case of sludge samples collected in winter, followed by rainy and summer seasons. It appears that pH was not varied systematically with sources of sludge. However, *p*H of all sludge samples across the seasons was acidic in nature, which concurred with earlier findings of Golui *et al*. (2014), Verma *et al.* (2019) and Roy *et al.* (2019). This is ascribed to the high organic matter content of sludge, which usually generate different organic acids, humus, acid salts during decomposition. Presence of carboxylic (-COOH) and phenolic (-OH) groups in humus are capable of attracting and dissociating hydrogen (H^+) ions (Das 2015). Electrical conductivity (EC) in sludges ranged from 3.17–7.69, 3.15–6.78 and 1.86–3.29 dS/m in summer, rainy and winter seasons, respectively (Table 1) and the corresponding mean value of EC were 4.79, 5.02 and 2.71 dS/m. EC varied significantly with sludge sources. On an average, the highest EC was recorded as 5.74 dS/m in sludge sample collected from Delhi Gate Nalla and lowest value of EC (2.95 dS/m) was observed in Nilothi. The higher value of EC in the sludge samples may be due to presence of dissolved salts and different ions, whereas higher mean value of EC in rainy season may be due to addition of salts and ions through runoff from adjacent area of drain carrying sewage water. Similar values of EC for sludge were earlier reported by Singh and Agrawal (2010a), Singh and Agrawal (2010b), Latare *et al.* (2014), Mtshali *et al*. (2014) and Mohamed *et al.* (2018).

Total carbon content in sludge: On an average, total carbon (TC) content in sludge was 18.0, 20.1 and 23.2% in summer, rainy and winter seasons, respectively (Fig 1). It was increased by 11.6% in rainy season and increased by 28.8% in winter with reference to summer. The TC content varied significantly from 13.2% (on dry weight basis) in Nilothi sludge to 30.1% in Keshopur sludge. The variation in TC content in sludge may be attributed to the different types of organic materials added to the sludge leading to differential rate of mineralization processes (Garcia-Delgado *et al.* 2007). Among the eight sources, there was not much variation in the TC content in sludge. There was a slight decrease in the TC with the samples of summer season may

Table 1 Seasonal variations in pH and electrical conductivity of sludge collected from different sewage treatment plants of Delhi

Treatment plants (source)	pH				Electrical conductivity (dS/m)			
	Summer	Rainy	Winter	Mean	Summer	Rainy	Winter	Mean
Coronation Pillar	6.21 ± 0.01*	6.34 ± 0.02	6.46 ± 0.03	6.34	5.43 ± 0.12	6.78 ± 0.05	2.03 ± 0.03	4.74
Delhi Gate Nalla	6.03 ± 0.02	6.50 ± 0.01	6.65 ± 0.04	6.40	7.69 ± 0.14	6.23 ± 0.01	3.29 ± 0.06	5.74
Keshopur	6.38 ± 0.01	6.42 ± 0.02	6.50 ± 0.02	6.43	5.23 ± 0.09	4.74 ± 0.07	2.37 ± 0.04	4.11
Narella	6.56 ± 0.01	6.37 ± 0.04	7.01 ± 0.03	6.65	4.74 ± 0.07	5.19 ± 0.50	3.27 ± 0.04	4.40
Nilothi	6.04 ± 0.05	6.58 ± 0.01	6.65 ± 0.03	6.42	3.17 ± 0.06	3.83 ± 0.15	1.86 ± 0.07	2.95
Okhla	5.89 ± 0.02	6.59 ± 0.01	6.93 ± 0.03	6.47	4.91 ± 0.06	5.52 ± 0.05	2.95 ± 0.02	4.46
Pappankallan	6.17 ± 0.02	6.59 ± 0.01	6.50 ± 0.03	6.42	3.68 ± 0.02	3.15 ± 0.34	2.87 ± 0.03	3.23
Rithala	5.97 ± 0.02	6.45 ± 0.01	6.77 ± 0.04	6.40	3.47 ± 0.10	4.70 ± 0.02	3.02 ± 0.03	3.73
Mean	6.16	6.48	6.68		4.79	5.02	2.71	
LSD (P=0.05)	Season = 0.02, Source = 0.03, Season × Source = 0.05				Season = 0.10, Source = 0.17, Season × Source = 0.29			

*Values are expressed in the table as mean ± S.D.

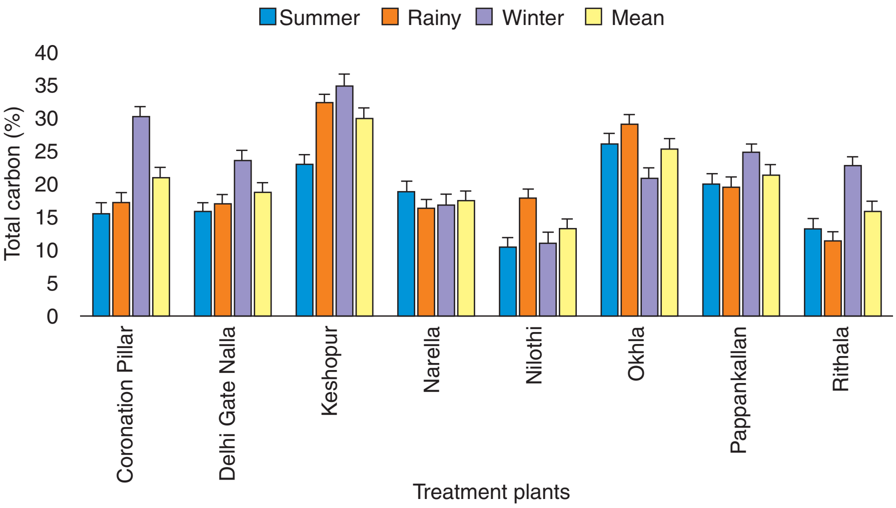

Fig 1 Seasonal variations in total carbon content of sludge collected from different sewage treatment plants of Delhi (LSD values are presented as error bar)

be due to washing away through rain water. Some earlier studies reported similar trend in TC content in sludges (Mendoza *et al.* 2006, Tu *et al.* 2012, Roy *et al.* 2019).

Macronutrients in sludge: Total nitrogen (N) content in sludges varied significantly among sources and the highest value being associated in Delhi Gate Nalla (2.51%) and the lowest value (1.29%) with Nilothi (Table 2). On an average, mean value of N content in sludge was 2.14, 1.81 and 1.99% in summer, rainy and winter season, respectively, which were within the reported ranges (Ahmed *et al.* 2010; Singh and Agrawal 2010a). Saha *et al*. (2017) observed that N content varied from 1.86–3.16% in sludge samples collected from various STPs of West Bengal. Presence of appreciable amount of N in sludge can be explained based on high amount of proteinaceous materials present in sludge (Serna and Pomares 1992). The lower N content during rainy season as compared to summer and winter might be due to under moist condition, higher rate of net mineralization of organic matter leads to formation of more mineral N, which may be lost by leaching. Also, excess moisture may cause reduced condition, which causes loss of N by denitrification (Roy *et al*. 2019). The highest mean value of P content was recorded in sludge samples collected during winter (1.47%) followed by rainy (1.22%) and summer (1.37%) seasons (Table 2). Mean values of total phosphorus (P) content in sludge samples collected from different sources followed the order as: Keshopur > Okhla > Delhi Gate Nalla > Coronation Pillar > Narella > Nilothi > Pappankallan > Rithala. The highest P content was recorded in sludge sample collected from Keshopur (1.94%) and the lowest P content was observed in Rithala sludge (0.95%). Similar findings on P content in sewage sludge were reported earlier by Singh and Agrawal (2008), Saha *et al*. (2017) and Roy *et al.* (2019) from various parts of the country. Presences of polyphosphorylated compounds from detergents in appreciable amount in waste water have been identified as the main source of P in sludge (Serna and Pomares 1992). Phosphorus content in sewage sludge generated from different cities, viz. Ahmedabad, Jaipur, Delhi, Nagpur and Chennai ranged from 0.82–2.34% (Maiti *et al.* 1992). The sludge samples collected from Keshopur STP showed the highest total potassium (K) content (0.34%) and the lowest was observed in sludge collected from Nilothi (0.17%) (Table 2). On an average, K content in sludge varied seasonally as summer > winter > rainy season. Ahmed *et al.* (2010) reported that the average content of K as 0.42%. The low K content in sludge as compared to N and P mainly due to K is water soluble and removed from the sludge through dewatering processes (Roy *et al.* 2019). The seasonal variation in K content may be due to excess moisture caused leaching of K during rainy season compared to summer and winter (Roy *et al.* 2019).

The sewage sludge obtained from eight different treatment plants (Coronation Pillar, Delhi Gate Nalla, Keshopur, Narella, Nilothi, Okhla, Papankallan and Rithala) varied widely among sources and seasons. The high total carbon (10.5–35.1%), N (1.21–2.64%) and P content (0.95–1.84%) in the sludge made them potential sources of plant nutrients and soil conditioner particularly in the face of escalating price of chemical fertilizer. Generally, Indian soil is poor in organic matter content, which is further aggravated due to limited availability of organic manures. In addition to this, application of sludge in soil also enhances soil biological properties (microbial biomass carbon and activities of different enzymes) and soil chemical properties, i.e. cation exchange capacity. In this context, application of sludge can be instrumental in enhancing the level of organic carbon and over all fertility status of soil.

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Table 2 Seasonal variations in macronutrient content of sludge collected from different sewage treatment plants of Delhi

Treatment plants (source)	Nitrogen (%)				Phosphorus (%)				Potassium (%)			
	Summer	Rainy	Winter	Mean	Summer	Rainy	Winter	Mean	Summer	Rainy	Winter	Mean
Coronation Pillar	1.84± 0.10*	1.87 ± 0.18	2.13 ± 0.21	1.95	1.24 ± 0.01	1.37 ± 0.02	1.35 ± 0.16	1.32	0.23 ± 0.01	0.20 ± 0.01	0.18 ± 0.01	0.20
Delhi Gate Nalla	2.58 ± 0.17	2.32 ± 0.11	2.64 ± 0.16	2.51	1.86 ± 0.02	1z.17 ± 0.01	1.43 ± 0.04	1.49	0.30 ± 0.01	0.26 ± 0.02	0.27 ± 0.03	0.28
Keshopur	2.96 ± 0.09	1.45 ± 0.11	2.44 ± 0.19	2.28	1.94 ± 0.23	1.51 ± 0.08	2.07 ± 0.15	1.84	0.32 ± 0.02	0.36 ± 0.02	0.35 ± 0.04	0.34
Narella	1.95 ± 0.08	1.67 ± 0.12	1.41 ± 0.24	1.68	1.18 ± 0.04	1.10 ± 0.02	1.15 ± 0.14	1.14	0.28 ± 0.01	0.18 ± 0.01	0.19 ± 0.01	0.22
Nilothi	1.40 ± 0.15	1.25 ± 0.09	1.21 ± 0.18	1.29	1.28 ± 0.06	1.24 ± 0.11	1.28 ± 0.12	1.27	0.16 ± 0.03	0.16 ± 0.01	0.19 ± 0.01	0.17
Okhla	2.50 ± 0.12	2.07 ± 0.16	1.25 ± 0.16	1.94	1.71 ± 0.04	1.61 ± 0.30	1.86 ± 0.15	1.73	0.27 ± 0.01	0.30 ± 0.01	0.34 ± 0.02	0.30
Pappankallan	2.36 ± 0.19	1.93 ± 0.12	2.50 ± 0.25	2.26	1.43 ± 0.02	0.88 ± 0.03	0.98 ± 0.05	1.10	0.23 ± 0.02	0.22 ± 0.01	0.19 ± 0.01	0.21
Rithala	1.51 ± 0.21	1.92 ± 0.30	2.36 ± 0.22	1.93	1.14 ± 0.06	0.87 ± 0.19	0.85 ± 0.13	0.95	0.23 ± 0.02	0.18 ± 0.01	0.17 ± 0.02	0.19
Mean	2.14	1.81	1.99		1.47	1.22	1.37		0.25	0.23	0.24	
LSD (P = 0.05)	Season = 0.12, Source = 0.20, Season × Source = 0.35				Season = 0.094, Source = 0.15, Season × Source = 0.27				Season= 0.012, Source = 0.019, Season × Source = 0.034			

*Values are expressed in the table as mean ± S.D.

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