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Assessment of physico-chemical properties of river bank soil of Yamuna in Allahabad city, Uttar Pradesh

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Abstract
The present study was conducted to assess the physico-chemical characters of Yamuna river bank soil at four sampling locations *viz.* Near Baksi Moda (L_1), Karelabug (L_2), New Yamuna Bridge (L_3) and Near Fort (Sangam) (L_4) in Allahabad city. Soil samples were collected from these 4 different stations for a period of 3 months (December’2017 to February’2018). The investigation revealed that the Physico-chemical status of the Yamuna River bank soil is fluctuated according to the prevailing environmental conditions. pH of soil across the sampling stations ranged between 6.61 ± 0.15 to 7.24 ± 0.24. Among all the stations the available nitrogen contain varies from 67.06 ± 1.82 kg ha^{-1} to 115.26 ± 6.55 kg ha^{-1}, the available phosphorus content varies from 2.83±1.39 kg ha^{-1} to 12.39± 6.26 kg ha^{-1} and potassium content 44.8 ± 11.20 kg ha^{-1} to 93.93 ± 39.33 kg ha^{-1}. The organic carbon values fluctuated from 0.2 ± 0.09 percent to 0.84 ± 0.20 percent. Sulphur concentration varies from 19.66 ± 13.97 mg kg^{-1} to 187.61±74.20 mg kg^{-1}. Soil texture of all the four sampling location was sandy in nature. Cluster analysis grouped four sites in three major clusters depending on the river bank soil characters and prevailing environmental conditions.

Keywords: Yamuna River, Allahabad, physico-chemical, soil, cluster analysis

Introduction

Rivers are one of the most precious elements of nature sustaining the mother Earth. Rivers play a major role in integrating and organizing the landscape, and molding the ecological setting of a basin. They are the prime factors controlling the global water cycle and in the hydrological cycle they are the most dynamic agents of transport (Raj and Azeez, 2009) [28]. Every year rivers carry a huge amount of top soils from its river bank area and deposit it in another part of its bank. In monsoon, due to flood it carries and deposit the maximum amount of soil in its bank; basically, these soils are alluvial in nature and also called as sediment. Sediment is the source of all nutrients in the river bank and most fertile for agricultural purposes. River Yamuna is the largest tributary of the Ganga River in North India. Its total length is around 1370 kilometers. Yamuna originates from the Yamunotri Glacier of Uttar Kashi in Uttar Pradesh and flows through the states of Delhi, Haryana and Uttar Pradesh, before merging with the Ganges at Sangam in Allahabad city. It is considered that approximately 57 million people depend on the river for their regular basic needs (CPCB, 2006) [6]. In the world, Yamuna is one of the most polluted rivers, especially along the Delhi segment, where about 22 drains discharge waste water into the river (CPCB, 2006; MOEF, 2013; Paul *et al*., 2014, Misra, 2010, Parmar and Singh, 2015) [6, 21, 27, 20. 25].The nutrients and pollution causing agents can easily transfer from water to soil and vice- versa. Good soil health ensures sustainable agriculture and ecological balance.

The physico-chemical characters of water of Yamuna and other river waters have been assessed from time to time at different places by many workers (Singh *et al*., 2005; Singh *et al.*, 2008; Suthar *et al.*, 2010, Misra, 2010, Parmar and Singh, 2015) [25, 31, 36, 20, 25]. Mandal *et al.* (2015) [25] has investigated physico-chemical properties of contaminated soil samples from four segments (Himalayan, Upper, Delhi, and Eutrophicated) of Yamuna riverbed. Very little previous investigation was found on physico-chemical properties of soil of Yamuna river bed. Moreover, studies have not been conducted previously on the physico-chemical properties of soil of Yamuna river bed of Allahabad city. Therefore, present study has been designed to investigate soil quality in selected sites along the

Yamuna river bank in Allahabad city region during December 2017 to February 2018.

Materials and Methods

Study Area

Allahabad city is in Southern part of Uttar Pradesh, and the administrative headquarter of Allahabad district. It is considered as the holiest of pilgrimage centers of India and is crowned in ancient scriptures as 'Prayag' or 'Teertharaj'. It is situated at the confluence of three rivers namely Ganga, Yamuna and the Saraswati. The meeting point is known as Triveni and is very sacred to Hindus. The city is located on the bank of river Yamuna at 25.27°N latitude and 81.51°E longitude spanning an area of 203 square km at an altitude of 98 meters above the mean sea level.

Sample collection and analysis

River bank soil (depth 0-30cm) samples were collected in zip-lock polythene bags from selected sites on monthly basis in from December'2017 to February'2018. The collected river bank soil samples were first air dried at room temperature, then crushed using a wooden mallet and then sieved (2mm) for further analysis (Saha *et al.* 2001; Dalai *et al.* 2004) [29, 7].Bulk density (g cm^{-3}) was done by core method and Particle density (g cm^{-3}), Pore space (%) and Water holding capacity (%) or water retaining capacity (%) was done by using Graduated measuring cylinder (Muthuaval *et al.*,1992). Munsell Soil Colour Chart was used for the purpose of identifying soil colour (Munsell, 1971) [22] and Bouyoucos hydrometer was used for determining soil texture (Bouyoucos, 1927) [3]. Soil pH (1:2) (w/v) and Electric Conductivity (EC, dSm^{-1}) (w/v) was performed by using digital pH meter (Jackson, 1958) [14] and digital conductivity meter (Wilcox, 1950), respectively. The organic carbon content was determined by following Rapid titration method (Walkley, 1947) [39]. The Available Nitrogen (kg ha^{-1}). Phosphorus (mg kg^{-1}), Potassium (kg ha^{-1}.), Sulphur (mg kg^{-1}) and Calcium (meq ca/100g) respectively was determined by using K-jeldahl method (Subbiah and Asija, 1956) [35], Colorimetric method (Olsen *et al.*,1954) [24], Flame photometric method (Toth and Price, 1949) [37], Reduction method (Johnson and Hideo, 1952) and E.D.T.A. Titrimetric Method (El Mahi *et al.*,1987) [8], respectively.

Statistical analysis

Statistical analyses and cluster analysis (CA) were performed using Microsoft excel-2010 AND Paleontological Statistics Software Package (PAST version 2.17c).

Results and Discussion

The present study evaluates the physico-chemical status of the river bank soil at four selected locations along Yamuna River at Allahabad city. The results of soil parameters obtained in this study (mean ± SD) are summarized in Table 2. Soil properties such as amount of organic matter, texture, soil minerals and porosity are influenced by the bulk density of a soil. The highest value (1.37 ± 0.14) of bulk density was recorded at L_3 sampling point and the lowest value (1.16 ± 0.08) was recorded at L_2 location. This parameter is positively correlated with particle density, percentage porespace, pH and sand which ascertains that, bulk density of a soil is influenced by these parameters (Table 4). Particle density represents only soil particles and not the total volume that the soil particles and pore spaces occupy in the soil. The highest value (3.28 ± 0.75) of particle density was recorded at both L_1 and L_4 location and the lowest value (2.52 ± 0.33) was recorded at L_2. This parameter is positively correlated with percentage porespace, pH, Sand and Clay (Table 4).

Table-2 depicts that the maximum percentage porespace (56.5 ± 12.28) was calculated at L_1 sampling point and the minimum percentage porespace (53.29 ± 8.81) found at L_2 location. The percentage porespace is positively correlated (r=0.59) with clay (Table-4).

Water rising capacity is defined as the amount of water the soil can hold for the use of plants root for certain period of time (Yusuf, 2011). Clay soil held more water than sandy soil (Gabler *et al.* 2009). In present study, WRC exhibited positive correlation with silt and clay whereas negatively correlated with Sand (Table 4). Water rising capacity (%) was the highest (69.12 ± 3.27) at L_4 sampling site, this may be due to the maximum amount of clay content in the soil. On the other hand the lowest (51.03 ± 2.36) water rising capacity (%) was noted at L_3 location, this may be due to presence of the maximum amount of sand particles at the L_3 sampling site.

Soil Colour was determined by the visual observation of the soil sample. Soil colour of four sampling sites with respect to sampling months is given in table 3.

The relative proportion of soil separates (Sand, Silt and Clay) in a particular soil determines its texture. This soil property is an important characteristic that influence water retention capacity, aeration, drainage, and susceptibility to erosion which drives crop production and management. In the present study, the soil of four sampling sites was found to be sandy in nature with more than 85% sand property and very less amount of silt and clay property (Fig.2).

The H^+ ion concentration is in dynamic equilibrium with the majority of charged surface soil particles which defines pH of the soil (Alloway, 1997; Tukura *et al.*, 2009; Snober *et al.*, 2011) [1, 38, 33]. The plant growth, biochemical breakdown, solubility and absorption of colloids, activity of microorganisms etc. are known through soil pH (Brady and Weil, 2004) [4]. In the present work, pH of soil across the sampling stations ranged between 6.61 ± 0.15 to 7.24 ± 0.24 at L_2 and L_1 sampling sites, respectively. Pati *et al.* (2016) also observed approximate similar pH range i.e. 6.07-7.96 along 6 sampling sites of Mahanadi River Soil at Cuttack, Odisha. The preferable pH of any soil range between 6.5-7.5 which is count as a neutral soil, but with the increasing of the pH value in the soil towards 14; the soil organic matter content decreases (Liao, 2016). EC and soil pH always have a negative correlation, when pH increase, EC value goes down and vice-versa (https://www.pthorticulture.com/en/training-center/relationship-between fertility-extremes-and-growing-medium-ph/), the present study also reflect the similar negative correlation (r=-45) between pH and EC (Table 4). Irrespective of their nutrient adsorption, solubility and exchanging differences, soils having a pH value between 5.5 and 8 are considered as ideal for plant growth (Gazey and Davies, 2009) [10].

Soil electrical conductivity (EC) is a measurement that correlates with soil properties and affects soil texture, cation exchange capacity (CEC), drainage conditions, organic matter level, salinity, and subsoil characteristics (Solanki and Chavda,2012). Moreover, electrical conductivity is a good measure of dissolved solids (Singare *et al.*, 2011) [30]. Soil with 0-2 dSm^{-1} range of EC contain 0-0.1% salt and the soil is non-saline, soil with 2-4 dSm^{-1} range of EC contain 0.1% to 0.3% salt and soil is very slightly saline, whereas soil with 4-8 dSm^{-1} range of EC contain 0.3% to 0.5% salt and soil is moderately saline (Jaiswal, 2006) [15]. Present investigation revealed that, the maximum EC (7.1±0.09 dS m^{-1}) was found at L_4 and the soil is moderately saline in nature. On the other hand, the minimum EC (0.40±0.30 dS m^{-1}) was recorded at L_1(Table 2).

Soil organic carbon (OC) plays an important role as a source of plant nutrients and in maintaining the soil integrity (Solanki and Chavda, 2012). Soils with <0.20% organic carbon indicates very less organic carbon; 0.21%-0.40% indicates low OC; 0.41%-0.80% as medium and > 0.80% is considered as high OC with respect to Uttar Pradesh soil condition (Jaiswal, 2006) [15]. During present study, the organic carbon results ranges between 0.2 ± 0.09% and 0.84 ± 0.20%. The highest and the lowest percentage of organic carbon were observed at L_3 and L_2 sampling sites, respectively. Very low OC was found at L_3 sampling point, whereas L_1 and L_4 represents with low and medium percentage of organic carbon. This parameter is positively correlated with available nitrogen, phosphorus, potassium and sulphur which verify that high amount of OC increases nutrient availability. Moreover, the negative correlation (r= -0.92) between OC and sand confirm the findings of this study (Table 4).

The fertility and biodiversity in an aquatic system is greatly influenced by nitrogen concentration of the sediment (Kumar *et al.*, 2012) [17]. In present study, the highest (115.26 ± 6.55 kg ha^{-1}) concentration of total nitrogen was recorded at L_2 sampling point and the lowest (67.06 ± 1.82 kg ha^{-1}) concentration was found at L_1 location. The major proportion of Nitrogen in the soil is influenced due to organic matter present in the soil (Baruah, 1997) [2]. Table 4 depicts that the parameter is positively correlated with organic carbon (r=0.50).

Phosphorous is a second key nutrient found in the soil. Phosphorous content of water in aquatic systems is greatly influenced by bottom sediments. Sediments often play an important role in the uptake, storage and release of dissolved inorganic phosphorous in aquatic systems (Haggard, 2004) [11]. The maximum concentration of available phosphorus (12.37 ± 6.26 kg ha^{-1}) was recorded at L_2 followed by L_3 (4.94 ± 1.31 kg ha^{-1}) and L_4 (3.61 ± 3.33kg ha^{-1}) whereas the lowest (2.83 ± 1.39 kg ha^{-1}) concentration was found at L_1 i.e. upstream site. Kumar *et al.*, 2012 [17] observed positive correlation (r=0.56) between phosphate and nitrate during the study of geochemistry of Sabarmati River and Kharicut Canal, Ahmedabad, Gujarat. Similar result was noted in the present study (r=0.69).

Apart from nitrogen and phosphorous, potassium is a third major nutrient which is essential for plant growth. In current study, the highest and the lowest content of potassium was found at sites L_4 (93.93 ± 39.33 Kg ha^{-1}) and L_3 (44.8 ± 11.20 Kg ha^{-1}), respectively. Potassium bears positive correlations with water retain capacity, electric conductivity, organic carbon and available nitrogen (Table 4).

All living organisms utilize sulphur in the form of both mineral and organic sulphates. Evapo-transpiration induced advection is a major contributor to the transport of sulphate from the water column into the sediments (Choi *et al*, 2006). The present work revealed the maximum (187.61+74.20 mg kg^{-1}) sulphur content at L_2 and the minimum (19.66 ± 13.97 mg kg^{-1}) at upstream sampling point L_1(Table 2). Sulfur showed higher values in L_2 site this may be as a result of sewage water discharge at this point. Sulfur bears positive correlation with organic carbon and available phosphorus with r= 0.90 and r= 0.98 respectively (Table 4).

Calcium is positively charged ions (cations) held to the surface of clay and organic matter in soil by electrostatic charge. These cations exchange with cations in soil solution (Ingavale *et al.* 2012) [13]. Calcium content was found to be the highest (78.32 ± 7.50 meq/100g) at L_3 and the lowest (74.51 ± 4.80 meq/100g) at L_1 sampling site (Table 2) and is positively correlated with available nitrogen and electric conductivity (Table 4).

Multivariate statistical analysis

Cluster analysis (CA)

Similarity between the sampling sites during the study period was determined by Cluster analysis (CA). CA calculated the similarity among sapling location on the basis of physico-chemical characteristics of river bank soil along Yamuna river of Allahabad city and the results are depicted in Fig 3 showing a dendrogram. The dendrogram was generated using Bray-curtis similarity index. L_3 and L_1 showed 91% of similarity with each other. On the other hand, L_4 site showed 87% similarity and the site is placed separately. Moreover, L_2 sampling site showed less similarity with other three sites, which may be due to high anthropogenic pressure at the site.

Conclusion

The present study summarizes the variation of different physico-chemical properties of river bank soil along Yamuna at Allahabad city. The assessment of soil quality of river clearly indicates that midstream sampling locations of the river systems are affected by anthropogenic activities. The present study reveals that Yamuna river bank soils in the Allahabad city contain very less amount of macro nutrients *i.e.* Nitrogen, Phosphorus and Potassium. L_2 Location shows comparative higher value of organic carbon (0.84 ± 0.20%) and sulphur (187.61+74.20 mg kg^{-1}) this may be due to sewage water outfall at the location. All the four location exhibits pH in between 6.61 ± 0.15 to 7.24 ± 0.24. However the EC value shows that the soil of L_1, L_2 and L_3 locations were non saline in nature and L_4 was moderately saline in nature. The present study will serve as a primary input to understand the soil pollution along Yamuna River and monitoring the river bank soil health of the study area. Moreover, the data will be useful to the environmentalist, conservation researchers and scientists for effective management of the Yamuna river ecosystem.

Table 1: Details of four sampling sites along Yamuna River, Allahabad City

Site code	Location	GPS coordinates	Description
L_1	Near Baksi Moda	25 ˚23’ 31.24 ’’ N 81 ˚ 48’ 15.80 ’’ E	L_1 sampling point represented as upstream of Yamuna river in Allahabad City and the area is surrounded by Agricultural land. In the area new bridge construction work is in progress and there are human interferences which includes cloth washing, bathing, Agricultural runoff and fishing.
L_2	Karelabug	25 ˚25’ 02.82 ’’ N 81 ˚ 49’ 21.05 ’’ E	It is approximately 3.34 km away from L_1 sampling point and represents the 1st midstream point of the river in the city. The major human disturbances include dumping of garbage, cloth washing, use of detergent, sewage water outfall into the river.
L_3	New Yamuna Bridge	25 ˚25’ 23.60 ’’ N 81 ˚ 51’ 29.86 ’’ E	It is approximately 3.63 km away from Karelabug and represents the 2nd midstreampoint of the river in the city.The human interferences include sand mining, disposal of garbage, input of sacred items, and fishing.

L_4	Near Fort (Sangam)	25 ˚25’ 42.57 ’’ N 81 ˚ 52’ 45.00 ’’ E	It is approximately 2.17 km away from new Yamuna bridge and represents the lower stream of the river in the city. The major human interferences include mass bathing in the time of Maghmela (December), dumping of sacred items, cloth washing and fishing.

Table 2: Physico-chemical parameter levels (mean ± SD, n=4) of river bank soil at selected sites of the Yamuna in Allahabad city

Parameters	L_1	L_2	L_3	L_4
Bulk Density (g cm^{-3})	1.36 ± 0.05	1.16 ± 0.08	1.37 ± 0.14	1.33 ± 0.18
Particle Density (g cm^{-3})	3.28 ± 0.75	2.52 ± 0.33	3.15 ± 0.31	3.28 ± 0.75
Percentage Pore space (%)	56.5 ± 12.28	53.29 ± 8.81	54.97 + 8.25	54.97 ± 12.09
Water Retaining Capacity (%)	56.15 ± 1.37	57.24 ± 2.76	51.03 ± 2.36	69.12 ± 3.27
P^H (1:2) w/v	7.24 ± 0.24	6.61 ± 0.15	6.86 ± 0.07	6.69 ± 0.08
Electrical Conductivity (dSm^{-1})	0.4 0 ± 0.30	1.06 ± 0.27	0.51 ± 0.40	7.1 ± 0.09
Organic Carbon (%)	0.36 ± 0.16	0.84 ± 0.20	0.2 ± 0.09	0.48 ± 0.18
Available Nitrogen (Kg ha^{-1}.)	67.06 ± 1.82	115.26 ± 6.55	102.69 ± 1.82	104.78 ± 6.53
Available Phosphorus (kg ha^{-1})	2.83±1.39	12.37 ± 6.26	4.94±1.31	3.61±3.33
Potassium (Kg ha^{-1})	52.27 ± 6.47	78.4 ± 0.01	44.8 ± 11.20	93.93 ± 39.33
Sulphur (mg kg^{-1})	19.66 ± 13.97	187.61+74.20	26.5 ± 12.48	23.58 ± 15.86
Calcium (Meq ca/100g)	74.51 ± 4.80	75.67 ± 14.61	78.32 ± 7.50	77.46 ± 16.80

Table 3: Soil colour at four selected locations along Yamuna River Bank, Allahabad city

Months	Colour	L-1	L-2	L-3	L-4
December	Dry	LYB (10YR 6/4)	PB (10YR6/3)	VPB (10YR7/3)	YB (10YR5/4)
	Wet	DB (10YR3/3)	DGB (10YR4/2)	B (10YR5/3)	DGB (10YR4/3)
January	Dry	PB (10YR6/3)	PB (10YR6/3)	PB (10YR6/3)	DB (10YR5/3)
	Wet	DB to B (10YR4/3)	B (10YR5/3)	DB (10YR3/3)	B (10YR5/3)
February	Dry	PB (10YR6/3)	LBG (10YR6/2)	PB (10YR6/3)	PB (10YR6/3)
	Wet	DGB (10YR4/2)	DGB (10YR4/2)	B (10YR5/3)	DGB (10YR4/2)

Note :- LYB- Light Yellowish Brown; PB- Pale Brown; VPB - Very Pale Brown; YB - Yellowish Brown; DB - Dark Brown; DGB- Dark Greyish Brown; B- Brown; LBG - Light Brownish Gray

Table 4: Correlation matrix among various soil quality parameters

	BD	PD	% Pore-space	WRC	pH	EC	OC	Avl. N	Avl. P	K	S	Ca	Sand	Silt	Clay
BD	1.00														
PD	0.95	1.00													
% Pore-space	0.85	0.87	1.00												
WRC	-0.07	0.22	-0.05	1.00											
pH	0.64	0.59	0.91	-0.37	1.00										
EC	0.08	0.32	-0.07	0.95	-0.45	1.00									
OC	-0.96	-0.83	-0.74	0.31	-0.59	0.11	1.00								
Avl. N	-0.60	-0.62	-0.93	0.18	-0.98	0.30	0.50	1.00							
Avl. P	-0.95	-1.00	-0.91	-0.18	-0.66	-0.27	0.83	0.69	1.00						
K	-0.48	-0.22	-0.46	0.90	-0.68	0.83	0.65	0.51	0.26	1.00					
S	-0.98	-0.99	-0.85	-0.11	-0.59	-0.25	0.90	0.59	0.98	0.32	1.00				
Ca	0.30	0.21	-0.24	0.06	-0.49	0.37	-0.41	0.57	-0.13	0.05	-0.29	1.00			
Sand	0.77	0.54	0.46	-0.58	0.41	-0.33	-0.92	-0.25	-0.53	-0.78	-0.66	0.53	1.00		
Silt	-0.79	-0.58	-0.66	0.67	-0.70	0.52	0.91	0.56	0.60	0.91	0.67	-0.19	-0.93	1.00	
Clay	0.33	0.60	0.59	0.72	0.37	0.59	-0.06	-0.55	-0.61	0.42	-0.48	-0.38	-0.34	0.20	1.00

Note: BD=Bulk Density, PD= Particle Density, WRC= Water retain capacity, EC= Electric Conductivity, OC= Organic Carbon, Avl. N= Available Nitrogen, Avl. P= Available Phosphorus, K= Potassium, S= Sulphur, Ca= Calcium

Fig.1. Map showing study area and selected sampling sites along Yamuna River, Allahabad City

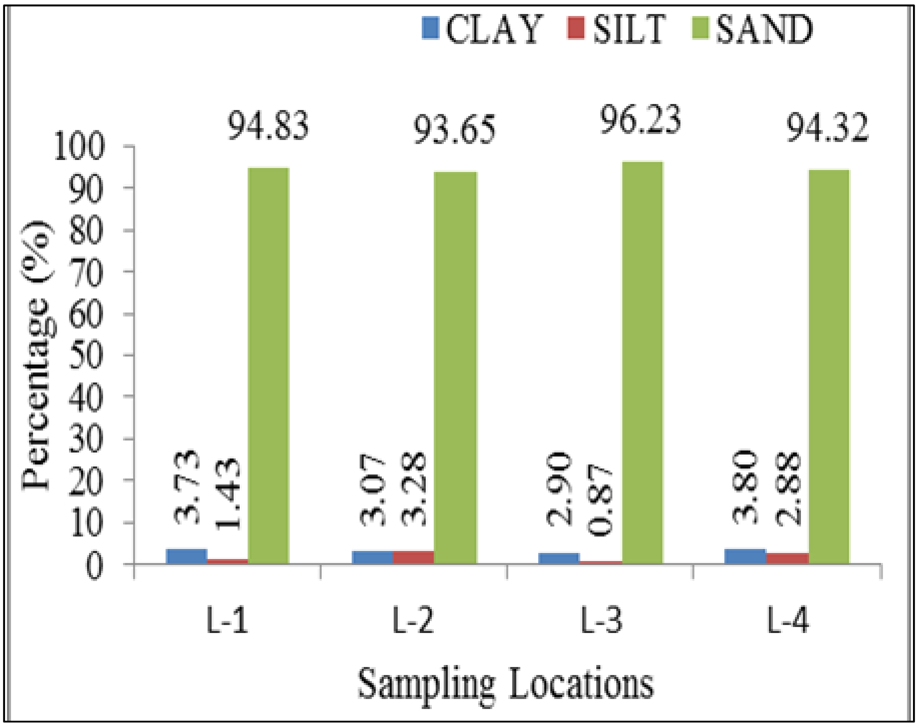

Fig 2: Soil texture of 4 sampling sites along Yamuna River, Allahabad City

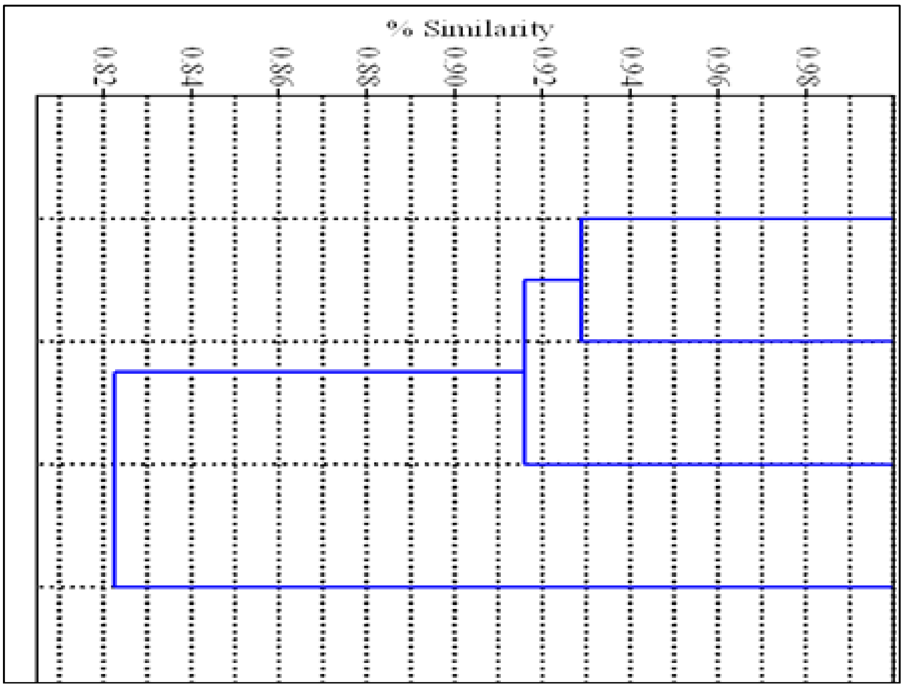

Fig 3: Bray-curties -similarity index on the basis of River Bank soil quality along Yamuna, Allahabad district

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