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ASSESSMENT OF SPATIAL DETERIORATION OF SOIL PROPERTIES OF SONEPURBAZARI OPEN CAST MINE, WEST BENGAL – A STATISTICAL ANALYSIS BY ANOVA TECHNIQUE

Subhankar Naha[1], Pritam Ghosh[2] and Mallicka Banerjee[3]
[1,3]Department of Geography, Naba Barrackpur Prafulla Chandra Mahavidyalaya, West Bengal, India
[2]Student, Ramakrishna Mission Brahmananda College of Education, Kolkata, West Bengal, India
E-mails: [1]subhankarnaha7@gmail.com [2]pritamghosh802@gmail.com [3]mbanerjee1982@gmail.com

Abstract: The present study comprises spatial analysis of soil parameters of sonepurbazari open cast mine, west Bengal, India. Mining of mineral resources results in extensive soil damage from different aspect, altering microbial communities and affecting vegetation growth leading to destruction of vast amount of land. In order to asses spatial deterioration of soil quality of this open cast mine and surrounding soil, soil samples were collected from different areas like new mine dump, old mine dump and native soil of surrounding agricultural land. In the present study different soil parameters physical and chemical have been analyzed. Altogether 27 samples have been collected from different spatial units of mine dumps and surrounding native soil of the study area. All samples are collected in the month of January, 2019.one interpolation technique has been used in geographical information system (GIS) environment to analyze the spatial difference in impact of soil parameters in the study area. From the result it shows that there is a significant difference in the soil properties between soil samples of old mine dump, new mine dump and native soil. Deteriorated soil also affected the productivity of surrounding agricultural lands. ANOVA analyses also have been done to see significant changes in soil properties due to mining activities.
Keywords: Mine, Soil quality, Native soil, Erosion, Deteriorate.

Introduction

Soil quality assessment can be regard as a key parameters for evaluation of environmental contamination in the ecosystem. Coal mining can adversely contaminate the nearby soils of mining area through the atmospheric deposition, and this deposition is one of the major sources of soil pollution (Ghose2007). It was estimated that a open-pit coal mine in a country like India can emitted 9366.7 kg of suspended particles per year which accounts for 3.74 kg of suspended particles per Mg of coal produced (Mukhopadhyay et al., 2014).Mainly this huge amounts of dust generated by Various mining activities like top-soil handling, drilling, blasting, overburden-handling by draglines and conveyors; coal handling, loading, unloading, etc. and which ultimately settle on nearby soils (Maiti, 2007). The coal dust deposition, soil

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erosion and sedimentation can be control by the vegetation on the mine spoil. Mining activities also affect the surface vegetation and soil quality. The main problem is Soil is an invaluable natural resource and its very important to conserved the soil quality. The economical, geological, environmental, social and human health issues are indirectly related to the quality of the soil (Kundu et al., 1998).

To understand or evaluate any deterioration in soil properties mine spoil characteristics of the dump area and the native soil are need to analyzed critically. The required nutrient level in the soil of mine spoil is less than that of the native soil in the mining area (Wilson et al., 2002). According to the quantity of Available nutrients (N, P, K) and exchangeable cation (Ca, Mg, Na, K) of the native soil it is clear that open cast mining changes the soil quality around the mining area (Bahrami et al., 2010). Other physical properties of mine spoil such as bulk density, water holding capacity, moisture contents are comparatively lower than the native soil. Mining method alters the soil texture from siltyloam to sandy soil. But some old mine spoils has regenerated from sandy loam to sandy clay loam type in this area. But no such significant differences in trace metal content in mine spoil and native soilcan not be found anywhere (Verma, 2003).

Research Objectives

1. To assess the spatial impact of open cast mining on the quality of Soil in and around the mining area of Sonepur Bazari in Pandabeswar Block of Burdwan District, West Bengal.
2. To analysis the significant difference among soil quality of different areas by applying ANOVA technique.

Materials & methods

Description of the Study Area

Raniganj coalfield is located in the Asansol and Durgapur subdivisions of Bardhaman district, West Bengal, India, which covers an area of 443.50 km2 and has a total coal reserve of 8552.85 million t. The reported coal reserves are 29.72 billion that make it the second largest coalfield in the country (in terms of reserves). The present study area are belongs to the ECL (Eastern Coal Field Limited) Which lies under Raniganj Coal field West Bengal, India. This study has been carried out in the open cast coal mines, namely Sonepur Bazari coal mine and their adjoining areas. The study area falls within the Survey of India toposheet number 73 M/2 and is bounded within latitudes from 23°42'35.59"N, and 23°39'53.30"N To longitudes from 87°10'49.39"E, and 87°15'1.04"E.

Sampling

Before starting with the research work, various literature works from books, journals, reports from different authors has been studied in order to understand various aspects of the mine pollution We have also used Google earth images. Soil samples are collected spatially from various points around the mining site to see spatial differences in soil quality and its impact from mining activity. GPS points were also taken in order to find the absolute latitude and longitude of the samples location. After collecting the samples are brought to the laboratory for further collected from the SonepurBazari Open Cast Mine area.

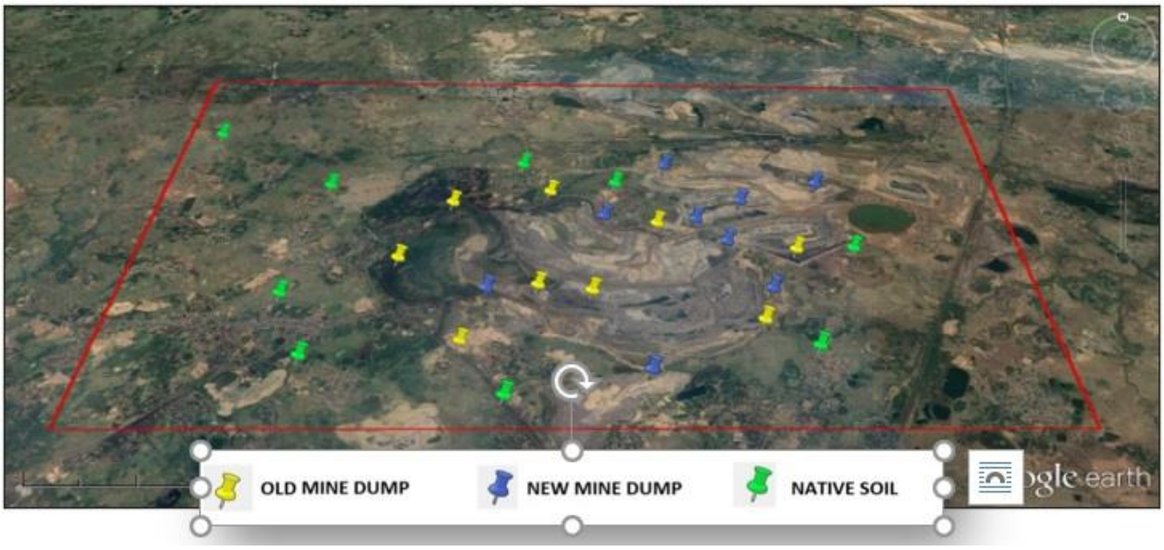

Fig 1 Spatial location of different soil samples in the study area

Soil quality analysis:

Soil samples were collected from overburden mine dumps (old & new) and nearest native soil from the surrounding areas of the open cast mine where local vegetation is already established and agricultural activity in progress. Then the collected samples were air dried at room temperature of 30 to 35 degree centigrade. Then the samples used in the laboratory and lightly crushed with mortar-pastel and passed through 2 mm sieve. After that the mine spoil and native soil samples were analyzed for the 846 physico-chemical properties by standard procedure in laboratories. All sample has been separated for measurement of different physical and chemical properties including soil PH, electrical conductivity, organic carbon, available nitrogen, phosphorous, potassium, cation exchange capacity, bulk density moisture content, and water holding capacity.

Table 1: Methods and Instruments used to analyze different soil parameters

Parameters	Methods and Instruments
1. Soil pH	Systronic pH meter model (Systronics micro pH meter 361) with glass electrode (Jackson, 1973).
2. Electrical Conductivity	Systronic EC meter, Model: Systronics micro conductivity meter 306.
3. Organic Carbon	Wet oxidation method of walkely-black method (Jackson, 1973).
4. Available Nitrogen	Methods of Tandon (Tandon HLS,1993).
5. Available Phosphorus	Olsen method and Kurtz method was used (Tandon HLS, 1993).
6. Available Potasium	Olsen method was used (Jackson,1958).
7. Cation exchange capacity (CEC)	Sodium acetate method was used (IS 2720, Part XXIV).
8. Bulk Density	Excavation method was used (Black, 1965).
9. Moisture content:	Measurement of weight method is applied (Desai, 1986).
10. Water holding capacity	Soil Keen’s box method was used (Black ,1965).
11.Mechanical Composition	Different sized particles was separated following the international pipette method after pretreatment of the samples i.e., removing organic carbon by H_2O_2 (30%) and bicarbonate-dithionite-citrate was treated to remove free iron oxide, 2% Na_2Co_3 (pH9.5) was used for effective dispersion

Data analysis

In the present study a geostatistical technique has been used (Bhunia et al., 2018). In this study interpolation method in a geographical information system (GIS) environment mainly IDW (inverse distance waiting) method has been used with the help of ARC-GIS software, basically to show the spatial deterioration condition of soil parameters.

Statistical analysis of the final results was done with the help of Excel, SPSS 16. Centrality value, Range and Standard deviation have been calculated to understand the spatial difference among three clusters. Total 14 parameters have been analyzed through the centrality indices. Again deviation index has calculated to measure the spatial variation of each parameter. Statistical significance of the differences among these clusters was measured by one way ANOVA.

Result and Discussion

Descriptive statistical analysis of soil properties:

As the samples are collected from different location on the old mine dump area, new mine dump area and from the part of native soil which is little far from the mining area to mainly show the spatial difference in deterioration of soil properties due to mining activity.

The result of analyzed variables e.g. pH, Electrical conductivity (EC), organic carbon (OC), Total Nitrogen (N), Organic Matter (OM), Potassium (K), Phosphorus (P), bulk density, moisture, cation exchange capacity, water holding capacity, amount of silt, sand, clay and porosity is summarized in the Table 2. Minimum, maximum value was calculated to estimates the variability among soil properties and average value of every soil properties also used to show the spatial differences among different areas of sample in terms of soil quality.

Presents study reveals that open cast mining has changed the soil texture from clay loam to sandy loam in and around mining areas, which holds less water and nutrients and affects plant growth. Here average % of clay is higher (35.106) than other old (21.051) and new mine dump (22.108) areas. On the other side sand particles % is higher in soil of old (59.458) and new mine dump (57.152) than native soil (39.805) so with the changing soil texture Condition soil moisture and water holding capacity also affected by this change spatially. As soil moisture is very important for the growth of plants, so it is evident from the study that average moisture content (%) of Native soil is higher (4. 525) than old mine dump (1.115) and new mine dump (1.473).

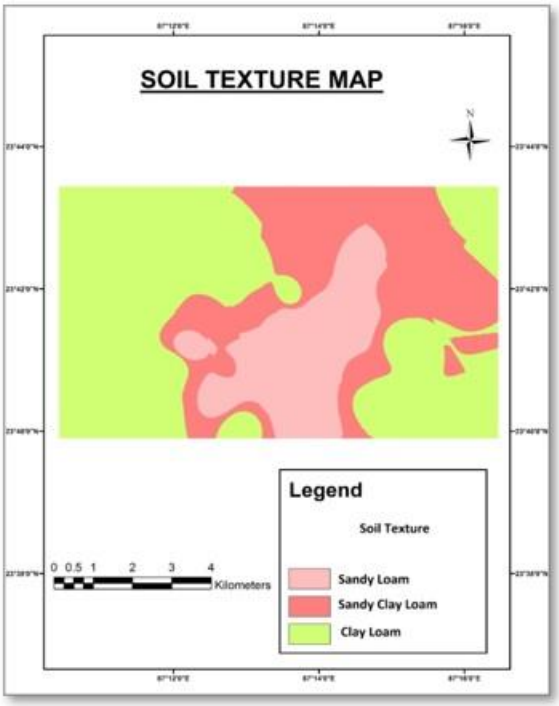

Fig 2: Spatial distribution of soil texture using IDW (inverse distance waiting)

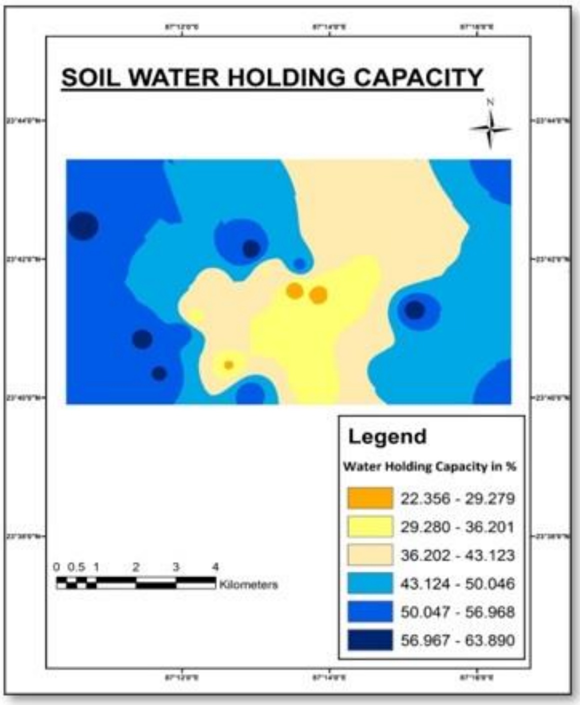

Fig 3: Spatial distribution of Soil Water Holding Capacity using IDW (inverse distance waiting)

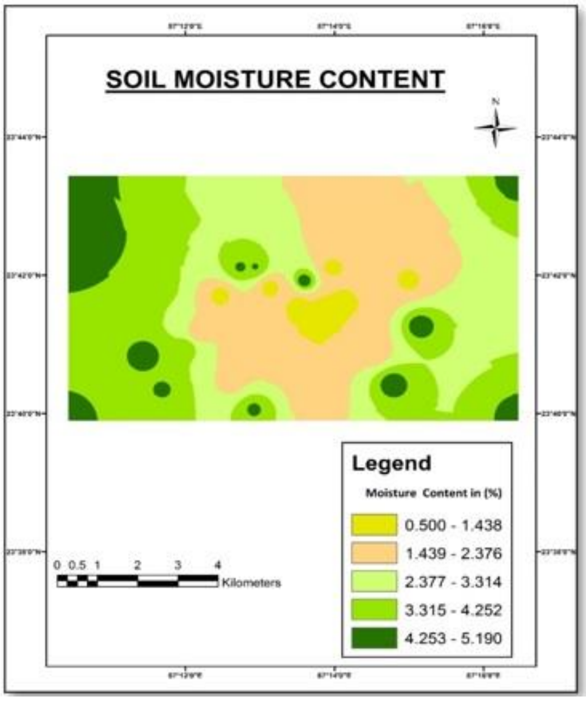

Fig 4: Spatial distribution of Soil moisture content using IDW (inverse distance waiting)

From the result it can be stated that due to less moisture content new mine dump and old mine dump area has become nearly vegetation less. The water holding capacity of soil depends on the texture of the soil. Presence of more clay particles increases water holding capacity. So, from the study it can be stated that native soil has higher clay content than both old and new mine dump area which also reflects on the growth condition of pants there. From the maps it is very clear that how texture condition, water holding capacity and soil moisture content of soil are spatially different. Spatial relations between these three parameters are clearly visible.

Table 2: The value of different physic-chemical parameters and their max, min, mean, and standard deviation as well as standard reference value for respective parameter

Parameter	Spatial Location	Max.	Min.	Mean	SD	SD of three spatial Mean value
pH	Old Mine	6.98	5.57	6.46	0.384	0.524309
	New Mine	7.23	5.49	6.32	0.531	
	Native Soil	8.12	6.46	7.29	0.597	
EC (dsm-1)	Old Mine	0.49	0.12	0.304	0.126	0.572198
	New Mine	0.48	0.12	0.343	0.134	
	Native Soil	1.54	1.06	1.314	0.145	
O.C	Old Mine	0.79	0.56	0.673	0.077	0.369248

	New Mine	0.87	0.32	0.585	0.168	
	Native Soil	1.46	1.01	1.264	0.150	
N (kg/ha)	Old Mine	469.7	203.2	380.395	87.460	169.549
	New Mine	523.12	361.2	460.457	53.409	
	Native Soil	745.32	682.01	705.791	20.161	
P (kg/ha)	Old Mine	10.61	4.53	8.212	2.363	4.654601
	New Mine	9.07	4.96	7.001	1.541	
	Native Soil	16.69	14.23	15.60	0.737	
K (kg/ha)	Old Mine	134.43	102.25	120.528	11.350	58.95431
	New Mine	139.55	77.95	114.641	20.612	
	Native Soil	212.12	193.54	203.35	6.689	
BD gm/cc	Old Mine	1.58	1.24	1.412	0.096	0.251814
	New Mine	1.59	1.35	1.462	0.081	
	Native Soil	1.11	0.93	1.003	0.059	
Moisture (%)	Old Mine	1.87	0.5	1.115	0.445	1.873987
	New Mine	1.79	0.7	1.473	0.368	
	Native Soil	5.18	3.87	4.525	0.666	
Clay (%)	Old Mine	26.16	12.16	21.051	4.246	7.827391
	New Mine	28.16	10.16	22.108	5.607	
	Native Soil	38.51	30.26	35.106	2.782	
Silt (%)	Old Mine	25	16	22.233	2.741	2.209606
	New Mine	24	18.67	20.738	1.965	
	Native Soil	28.53	22.17	25.087	2.072	
Sand (%)	Old Mine	62.84	51.84	59.458	3.291	10.74303
	New Mine	67.84	47.84	57.152	6.231	
	Native Soil	45.38	36.27	39.805	3.135	
CEC	Old Mine	4.34	3.78	4.096	0.186	2.663616
	New Mine	4.77	3.31	4.111	0.466	
	Native Soil	10.07	7.75	8.717	0.883	
WHC (%)	Old Mine	39.75	31.25	33.72	4.129	12.46835
	New Mine	42.36	22.32	35.613	6.316	
	Native Soil	63.92	47.64	56.200	5.163	

Porosity (%)	Old Mine	42.98	40	41.588	0.987	4.687462
	New Mine	45.32	40.01	41.946	1.558	
	Native Soil	50.51	48.58	49.880	0.637	

Ec: electrical conductivity, oc: organic carbon, N: nitrogen, P: phosphrous, K: potassium, BD: bulk density, CEC: cation exchange capacity, WHC: water holding capacity

Bulk density is defined as the mass (weight) per unit volume of a dry soil including pore space and is expressed in mg 3 or gm cc (Mahapatra et .al, 2012)). Bulk density is important for the gaseous exchange in the soil, but high bulk density would pose restriction to growth of deeper rooted plants and for gaseous exchange also. In this study bulk density of native soil is comparatively lower than old mine and new mine dump. As dumping sites in the mine areas are evidently influenced by the machinery activities and due to excavation from deep part of the crust the presence of hard rock is higher in mine spoil which makes soil bulk density higher and unfertile too near old and new mine dump.

Pore spaces of soil means it is the portion of soil volume not occupied by mineral, organic matter or any solid particles. Soil porosity is the volume percentage of total pore space in a soil. Here total average pore volume of native soil 49.87% which is higher than old and new mine dump. The open cast mine caused a large number of deforestation in the study area, which is being main reason behind low pore volume in the old and new mine soil.

Soil PH can be regarded as master variable in soil as it can be control many chemical processes in the soil. According to the result of the study area it shows that average ph value of native soil is higher (7.29) than old (6.46) and new mine dump (6.32). The increase in pH in native soil is probably due to the addition of organic matter and the effect of weathering for long time which modifies the pH of the native soil.

Soil organic carbon is one of the important factors for plant growth and soil fertility. Here soil organic carbon in the mine dumps (old and new) soil is lower than of the native soils. The mean value of organic carbon in the old mine dump and new mine dump is 0.673 % and 0.585% respectively which is 0.5 times lower than the native soil (1.245%). And this level of organic carbon in the mine dumps makes the soil unhealthy for the plant growth. Here in case of Mine dump the trees are completely absent so due to the lack of humus and other organic content the level of organic components is very lower. The disruption of the ecosystem functioning is also a big cause of lower organic content in the mine dumps.

Cation Exchange Capasity is used as a measure of nutrient retention capacity, soil fertility, and the capacity to protect groundwater from cation contamination. The mineral fertility is also depends on cation exchange capacity. Low cation exchange capacity observed mainly in old and new mine dump area which indicated lower productivity of plants. It can be seen that average value of CEC in old and new mine dump are 4.096and 4.111 respectively but in the native soil it is little higher (8.171).According to the study it also suggests that low cation exchange capacity has reduced soil organic carbon, water holding capacity, and nutrient properties of the soil which makes the completely unfertile like which is happening with the mine dumps.

The available nitrogen is an important factor to increase the soil fertility. Generally, normal soil contains 272-544 kg ha-1 of available nitrogen (Gupta et al., 2006).in the study area content of nitrogen (mean value) is higher in native soil (705.791) than old mine and new mine dump respectively. This result also showing how vegetation condition is being affected by this less presence of nitrogen content in soil in mine dump areas. The normal value of phosphorous in soil should be between 22.5 to 56 kg/ha (Gupta et al., 2006). Here mean value of spatially collected samples are very low than standard value mainly in old mine (8.212) and new mine (7.001) dump areas. Value of phosphorus is little better in native soil. The normal potassium content in the alluvial soil is in between 136 to 337.5 kg ha-1 (Gupta et al., 2006) but from the collected samples it can be seen that in the old and new mine dump areas it very less than standard value (120.528,114.641).

From the mean value of every parameter it is well understood that soil quality of the study area is degraded mainly in old and new mine dump areas and in the native soil it is also showing poor condition than Normal value. So it can be said that mining activity is having a major effect in the soil quality spatially and indirectly in the vegetation growth and environmental stability.

Standard deviation value indicates the strong spatial variability among the soil samples. According to the analyzed result it is clear that some of the samples having higher degree of variability like Nitrogen (N), Phosphorous(p), potassium (K), water holding capacity (WHC), Porosity, Clay and Sand particles etc.

Table 3: ANOVA test to show the mean differences between three clusters.

Parameters		SS	DF	MS	F	P level
pH	Between Groups	4.949	2	2.474	9.421	0.0009
	Within Groups	6.304	24	2.262		
	Total	11.253	26			

EC (dsm -1)	Between Groups	5.894	2	2.947	160.437	0.000
	Within Groups	0.440	24	0.018		
	Total	6.334	26			
O.C %	Between Groups	2.454	2	1.227	64.57	2.1940
	Within Groups	0.456	24	0.019		
	Total	2.910	26			
N (kg/ha)	Between Groups	517442	2	258721	71.152	0.000
	Within Groups	87267.08	24	3636.128		
	Total	604709.1	26			
P (kg/ha)	Between Groups	389.96	2	194.98	68.76	0.000
	Within Groups	68.051	24	2.835		
	Total	458.012	26			
K (kg/ha)	Between Groups	44289.81	2	22144.9	111.01	0.000
	Within Groups	4787.531	24	199.48		
	Total	49077.34	26			
BD (gm/cc)	Between Groups	1.141	2	0.5709	87.279	0.000
	Within Groups	0.157	24	0.0065		
	Total	1.298	26			
Moisture (%)	Between Groups	63.2165	2	31.608	184.94	0.000
	Within Groups	4.1018	24	0.1709		
	Total	67.3183	26			
Clay (%)	Between Groups	1102.859	2	551.4296	28.915	0.000
	Within Groups	457.6874	24	19.0703		
	Total	1560.547	26			
Silt (%)	Between Groups	87.882	2	43.941	8.4101	0.0017
	Within Groups	125.394	24	5.224		
	Total	213.277	26			
Sand (%)	Between Groups	2077.443	2	1038.722	52.381	0.000
	Within Groups	475.919	24	19.829		
	Total	2553.363	26			
CEC	Between Groups	127.6919	2	63.8459	185.6212	0.000
	Within Groups	8.2549	24	0.3439		
	Total	135.9469	26			
WHC (%)	Between Groups	2798.305	2	1399.153	50.2023	0.000
	Within Groups	668.886	24	27.8702		
	Total	3467.191	26			
Porosity (%)	Between Groups	395.4357	2	197.7179	155.6176	0.000
	Within Groups	30.4928	24	1.2705		
	Total	425.9286	26			

ANOVA is basically the collection of statistical tools to analyze the significant differences among the group means in sample set. Single factor One Way ANOVA to each parameter revealed that there are no significant mean differences in O.C in study area at $P < 0.05$. The mean differences among the three spatial units (Old mine, New mine and Native soil area) shows significantly differences for most of soil qualities including Ph, EC, N, P, K,BD, Moisture, Clay, Silt, Sand, CEC, WHC and Porosity. This test shows the high variation to most of the soil qualities related to their spatial unit. Thus, it is very clear that, the impact of mining activities on soil qualities is very prominent. And mining can be considered as the major reason of soil quality degradation in these areas.

Conclusion

Sonepurbazari of West bengal is one of the important coal mine. For a developing country like India every mining area is very important as they support energy supply and also make a major contribution in the economy of the country and respective state. But somewhere due to lack of proper infrastructure and loose management of surrounding areas, environmental condition is deteriorating. From the analysis it is very clear that there is vast spatial variation in the effects of coal mine and surrounding native soil areas. Result of analysis of physical and some chemical properties from different spatial units of mining are shows that many parameters are negative than standard value especially near coal mine dumps. But some sample from native soil showing better result than coal dumping areas. But still condition of productivity is being affected near or little far from the coal mine area due to degradation of soil. Here one way ANOVA techniques also confirmed the spatial variability among soil samples between old mine, new mine dump and native soil areas. It can be said that without proper implementation this kind of degradation in soil quality can aggravate the general productivity of the area thus leads to long-term impact on environmental stability.

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Author’s contributions

Pritam ghosh contributed to conception, design, and acquisition of data, data analysis and interpretation of data. Subhankar naha helped in the conceptualization of the topic and participated to acquisition of data, data analysis and interpretation of data as well as involved in drafting the primary manuscript. Mallicka Banerjee made a contribution in statistical analysis, in checking graphs, and revising the manuscript critically to fulfll the reviewer comments as well as maintaining the scientific merits with syntactic correctness for final submission of the manuscript. All authors read and approved the final manuscript.

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