

Soil Nutrient Variations Between Soil Depths (0-20cm & 20-40cm) Around Cement Factories, Ethiopia

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Abstract: This study was conducted with an aim to analyze the spatial variability of soil properties with depth under cement dust pollution areas. In soil there is nutrient variation in different depths, the variations can also be affected by the anthropogenic factors. In this study, the nutrient variation between soil depths (0-20cm & 20-40cm) in cement dust pollution fields has been assessed. A total of 72 soil samples from 0-20cm & 20-40cm depths at different distance from the factories (0-500m, 500-1500m & >4000m) were collected and analyzed at Holetta agricultural chemistry laboratory. The parameters analyzed include: major physico-chemical properties (Total Nitrogen, Organic carbon, Potassium, Phosphorus, pH, Moisture, soil texture, Bulk density, SO₄-S and Cation Exchange Capacity). One-way ANOVA was used to compare the mean values between experimental fields (distance from the factory and soil depths) with SPSS statistical software. At $p < 0.05$, there is no significant difference in the analyzed parameters between soil depths. However, trends have shown that the pH, Organic carbon, Total Nitrogen, clay content, Phosphorus, Potassium and Sulfur level declines top to bottom (from 0-20cm to 20-40cm depths). The trends of Soil bulk density increased from top to bottom, this might be due to loading effect. Electric conductivity declines with soil depths near to the factory but increased top to bottom as far from the factories. From the data, the cement dust pollution can influence nutrient variations and therefore needs to be monitored to regulate the pollution of emanated dust.

Keywords: Soil Depths, Physico-chemical Properties, Cement Dust

1. Introduction

Soil is of major importance for life since it represents a source of both water and nutrients for plants, soil-living microorganisms and animals. Metals and metalloids are significant natural components of all soils where their presence in the mineral fraction comprises a store of potentially-mobile metal species as important components of clays, minerals and iron and manganese oxides that, in turn, have a dramatic influence on soil geochemistry [1]. The associations among the soil properties also vary with the variation of depths. As the interface between the atmosphere, biosphere, and lithosphere, soil undergoes an intense vertical exchange of materials resulting in steep chemical and physical gradients from surface to bedrock. Human management system such as frequent plowing and tillage for the purpose of cultivation, grazing or similar uses also changes the proportions of many soil properties with

changing depths [2]. Accordingly, horizons may differ in organic matter content, structure, texture, pH, base saturation, cation exchange capacity (CEC), bulk density and water holding capacity, as well as many other soil physical and chemical properties. According to [3], variability in soil properties at the series level is often caused by small changes in topography that affect the transport and storage of water across and within the soil profile.

Environmental pollution related to urbanization and industrialization is inevitable unless proper measures are taken. Air pollution is one of the serious problems in recent times as a result of rapid increase in number of vehicles, cement factories, steel and coal industries and petrochemical industries coupled with deforestation of natural forest. Many researches investigated the impact of the cement dust on soil properties, plant growth and a contamination source of heavy metals [4-10]. The statement of the problem was devised from the farmers' complaints which the cement dust pollute

their agricultural fields. In this paper, the extent of pollutions to changes soil properties has been addressed. Therefore, the objective of this study was to examine the effects of soil depths in nutrient variations on some selected soil properties regarding to the cement dust pollutions.

2. Materials and Methods

2.1. Description of the Study Areas

The first study area is Muger, around Muger cement factory, which is located 90 km North West of Addis Ababa. It lays at an elevation of 2450 m above sea level. The average

wind speed at a height of 10 m above ground level was 1.0 km/h between October- November and 0.72 Km/h between April-May [11]. The farmers around in this area harvests cereal crops such as wheat, barley, teff and sorghum once in a year from October to November. The second study site is in Chanco, around Abyssinia cement factory, which is located 40 km north of Addis Ababa. It lays at an elevation of 2500 m above sea level. In this study area barley, wheat and teff are dominant cereal crops that harvests in November once in a year.

Three experimental treatments (0-500 m, 500-1500 m and \approx 4000 m from the factories) and two soil depths (0-20cm & 20-40cm) were chosen.

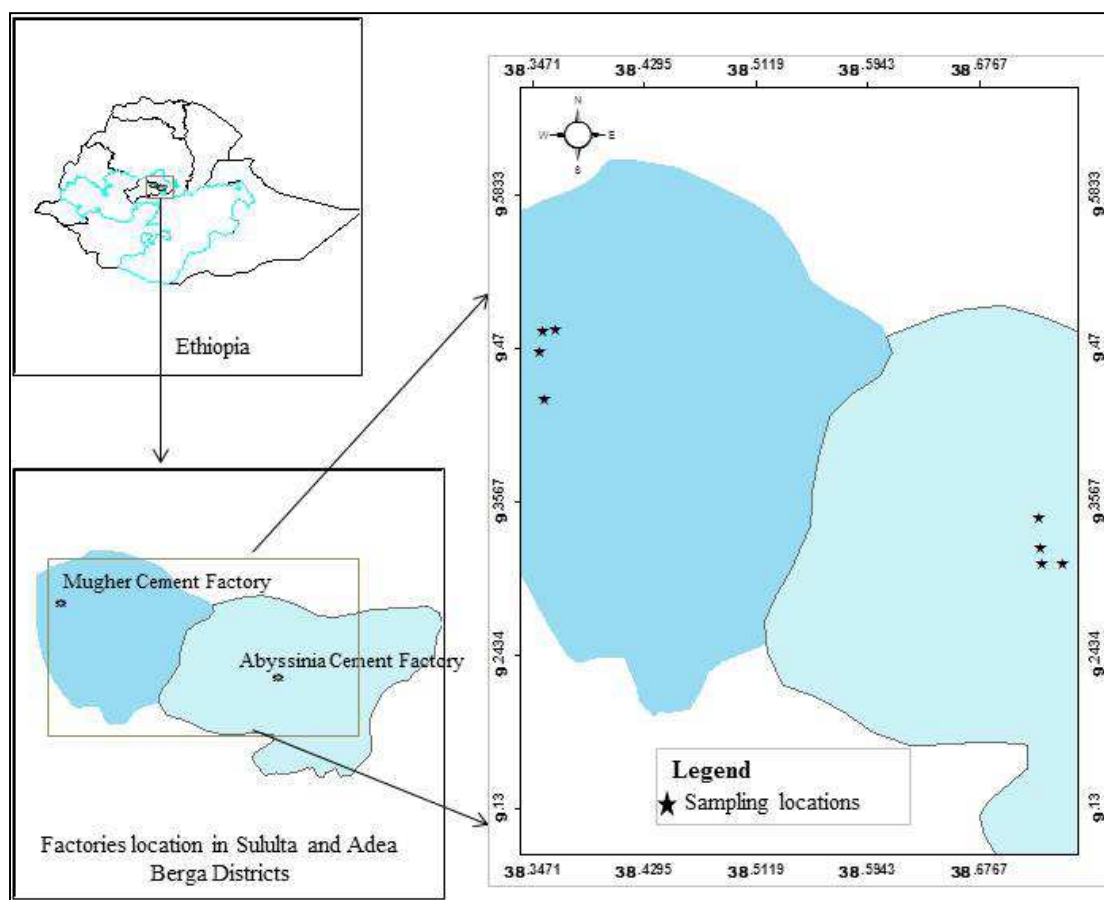


Figure 1. Location map of the study areas, North and West Shewa Zones, Oromiya region, Ethiopia.

2.2. Equipment and Reagents

The instruments and apparatus that used in this study were: Atomic Absorption spectrophotometer (Agilent, 200 Series AAS), Spectro photometer (Janway 6300), pH meter (HI 9017 microprocessor HANNA), conductivity meter (Janway 4310), analytical balance, pistel and mortar. All reagent chemical used were analytical grades; distilled water was used for dilution and preparation of reagents. Traceable to NIST stock solutions, 1000 ppm, were used to prepare a series of potassium working standards.

2.3. Sample Collections and Preparations

The soil samples were collected at the time of harvesting

the cereal crop at 0-20cm and 20-40cm depths. Random sampling techniques were followed from the experimental fields of: 0-500 m, 500-1500 m and \approx 4000m from the factories regards to the cement dust concentration gradients. With Auger, 1 kg a total of 72 soil samples were taken and core samplers used for bulk density sampling in separate.

Every sample was coded properly, the sample bags marked with codes using permanent marker. All the sample information regarding sampling locations, source, date of collection and allotted codes were recorded in the observation register and brought to Holetta Agricultural Research laboratory for preparation and analysis.

The collected soil samples were transferred to plastic trays and break up the large clods to speed up drying. The sample

then air-dried, crushed with mortar and pestle and passed through a 10-mesh (2-mm) and 0.5-mm opening stainless steel sieve [12, 13].

2.4. Laboratory Procedures

2.4.1. Moisture

5 g soil sample were weighed to moisture can with 0.001 g accuracy, dried overnight at 105°C, removed moisture can from oven, cooled in desiccator and weighed. The moisture content in wt % (w/w) is calculated by [12]:

$$\text{Moisture (wt \%)} = \frac{[\text{fresh weight} - \text{dry weight}]}{\text{dry weight}} \times 100 \quad (1)$$

2.4.2. Bulk Density (Core Method)

The collected soil samples in core sampler were weighed (soil + core sampler), dried overnight at 105°C, removed from oven, cooled in desiccator and weighed. The BD in g/cm³ calculated as [14].

$$BD = \frac{W_{tsc}}{V} \times 100 \quad (2)$$

$$\%(\text{Clay} + \text{Silt}) = R - B(\pm T)X \frac{100}{wt} \text{ from the first reading} \quad (3)$$

$$\% \text{ Clay} = R - B(\pm T)X \frac{100}{wt} \text{ from the second reading} \quad (4)$$

$$\% \text{ silt} = \%(\text{Clay} + \text{Silt}) - \% \text{ Clay} \quad (5)$$

$$\% \text{ Sand} = 100 - \%(\text{Clay} + \text{Silt}) \quad (6)$$

where: R = hydrometer reading, B = blank, T = Temperature

2.4.5. pH

The pH of soil sample was measured potentiometrically in the suspension of a 1:2 soil liquid mixtures. 20 g soil sample were weighed and poured 40 mL of distilled water. The mixture was allowed to stand for 30 min and measured by inserting electrode. Reading then taken (after 30 to 60 s) to the nearest 0.1 pH unit.

2.4.6. Total Nitrogen

The micro-kjeldahl procedure was followed. The samples were digested in concentrated sulphuric acid with selenium as catalyst. The solution was then made alkaline with 50% sodium hydroxide; the distillate (evolved ammonia) was trapped in 1% boric acid and titrated with standard acid with 0.1 M HCl [12].

2.4.7. Organic Carbon

The Walkley-Black procedure was followed. A wet combustion of the organic matter involved with a mixture of potassium dichromate and sulphuric acid. The residual dichromate were titrated against ferrous sulphate and reported as g/kg [12].

2.4.8. Phosphorus Soluble in Sodium Bicarbonate

The samples were extracted with a sodium bicarbonate solution of pH 8.5. Phosphate in the extract was determined colorimetrically with the blue ammonium molybdate method with ascorbic acid as reducing agent [13].

Where: V = volume of soil core ($\pi r^2 h$), W_{tsc} = Dried weight of sample.

2.4.3. Electrical Conductivity

20 g soil sample were weighed into a beaker, 20 mL water added, stirred thoroughly, and allow the suspension to stand for 15 to 20 min. The conductivity cell inserted to the suspension and read the electrical conductivity [15]. The result reported is in $\mu\text{S/cm}$.

2.4.4. Particle-size Analysis

40 g soil sample were weighed into 600 mL beakers, 5% 50 mL calgon solution and 25ml water were added. The beakers were covered with a watch glass and allowed to leave overnight. It was then transferred to the cup of mechanical stirrer and stirred for 5 minutes. The dispersed soils were transferred to a hydrometric jar and were mixed with a plunger. The mixture made to mark with distilled water. Reading was taken from immersed hydrometer. The jars were kept undisturbed for 3 hours and were taken the second reading. The result is reported as % clay, % silt and % sand [16].

2.4.9. Potassium and Cation Exchange Capacity

Ammonium acetate methods were followed to extract exchangeable potassium. 5 g soil sample weighed in 100 mL beaker and soaked overnight by 50 mL ammonium acetate. It was filtered and leached 5 times with 30 mL portion in 250 mL volumetric flask. The solutions kept for potassium determination. The residue further leached with 95% ethyl alcohol, distilled by alkaline with MgO for CEC determinations [17].

2.5. Statistical Analysis

Statistical analyses were carried out using SPSS software, version 20. One way ANOVA, descriptive statistics, was used for comparing the mean concentration of soils. Significance difference among soil depths indicated for each parameter at $p < 0.05$ and the results were reported as mean \pm standard deviation.

2.6. Data Quality Control

Appropriate quality assurance procedures and precautions were carried out to ensure reliability of the results. De-ionized water was used to the reagent preparation and sample dilution throughout the study. The analytical balances, drying oven and glass wares used in the laboratory were calibrated by the calibration body and certified to use it. Before begun

to the laboratory analysis, we were participated in proficiency test scheme in major physico-chemical parameters with the international proficiency test providers to see the competency of Holetta Agricultural research laboratory on delivery same test.

For each soil physico-chemical parameters of soil samples:

triplicate analyses were conducted together with the internal laboratory (Holetta agricultural research) control sample to verify the precision and accuracy of the results. Outliers between triplicates measurement of sample analysis were checked by verifying the % RSD (percent relative standard deviation).

3. Results and Discussions

Table 1. pH, EC, BD and Texture.

Location one, around Abyssinia cement factory						Location Two, around Muger cement factory		
Harvested crop	Parameters	Soil depths	mean±Sd			mean±Sd		
			Distance from the factory			Distance from the factory		
			0-500m	500-1500m	≈4000m	0-500m	500-1500m	≈4000m
Barley	pH	0-20cm	7.73±0.14a	6.54±0.30a	7.9±0.00a	8.09±0.14a	6.93±0.21a	5.86±0.00b
		20-40cm	7.57±0.33a	6.51±0.13a	7.89±0.00a	8.15±0.17a	6.98±0.17a	7.02±0.00a
	EC (µS/cm)	0-20cm	146.40±13.86a	87.03±19.64a	65.60±0.00b	133.08±18.29a	98.33±41.65a	68.00±0.00b
		20-40cm	116.77±18.08b	93.58±5.07a	69.90±0.00a	112.00±33.59a	80.73±33.22b	123.00±0.00a
	BD (g/cm³)	0-20cm	1.324±0.03a	1.289±0.03b	1.295±0.00a	1.280±0.08ab	1.305±0.07a	1.188±0.00b
		20-40cm	1.309±0.09a	1.364±0.106a	1.363±0.00a	1.296±0.12a	1.353±0.02a	1.337±0.00a
	Moisture (%)	0-20cm	17.05±3.47a	13.32±3.61b	12.13±0.00a	10.47±2.76a	9.20±2.24a	9.13±0.00a
		20-40cm	16.57±2.57a	17.75±6.87a	11.65±0.00a	10.74±2.24a	11.77±2.97a	8.64±0.00a
	Clay (%)	0-20cm	44.06±8.38a	30.00±2.50a	52.50±0.00b	46.25±16.89a	33.13±7.47a	50.00±0.00a
		20-40cm	45.31±9.91a	32.50±7.50a	60.00±0.00a	48.13±18.53a	35.62±5.54a	42.50±0.00a
	Texture Silt (%)	0-20cm	34.06±8.44a	43.15±6.57a	28.75±0.00b	20.00±2.04a	26.88±7.18b	25.00±0.00b
		20-40cm	34.06±12.60a	38.75±3.23a	26.25±0.00a	20.00±8.90a	22.5±7.36a	27.50±0.00a
	Sand (%)	0-20cm	21.88±3.15a	26.88±7.74b	18.75±0.00a	33.75±15.07a	40.00±5.40a	25.00±0.00b
		20-40cm	20.63±3.15b	28.75±8.90a	13.75±0.00b	31.88±11.06a	40.63±11.61a	30.00±0.00a

The significance difference between soil depths of PH, Ec, BD, Moisture and Texture at p<0.05 are indicated with 'a' and 'b'.

Soil pH is a crucial soil indicator defined as the negative log of the hydrogen ion activity. The pH range normally found in soils varies from 3 to 9. The significance of pH lies in its influence on availability of soil nutrients, solubility of toxic nutrient elements in the soil, physical breakdown of root cells, and CEC in soils whose colloids (clay/humus) are pH-dependent and biological activity. Most crops grow best when the soil pH is between 6.0 and 8.2. From the result, slightly acidic to moderately alkaline soil P^H was obtained. The PH value is higher at Top soil (0-20cm depth) and decline towards to surface soil (20-40cm depth). The PH variation between soils depths have not much as far from the factories (0-500m to 500-1500 m to ≈4000 m) might be due to the liming effects from cement dust. Particle size distribution (soil texture) is an important parameter in soil classification and has implications for soil water, aeration, and nutrient availability to plants. Laboratory procedures normally estimate percentage of sand (0.05 – 2.0 mm), silt (0.002 – 0.05 mm), and clay (<0.002 mm) fractions in soils. Soil texture triangle shows that the samples in the study area are clay to clay loam soil. The clay fractions between soil depths vary and decline from top to surface soil. Soil bulk density (BD) is ratio of the mass (oven-dry weight) of the soil to the bulk volume which includes the volume of both solids and pore space at specified soil water content (usually the moisture content at sampling). The trends have shown in the data bulk density consistently increased with increasing depth is might be due to loading effect of the top soils. Soil moisture influences crop growth not only by affecting nutrient availability, but also nutrient transformations and soil biological behavior. Soil

salinity refers to the concentration of soluble inorganic salts in the soil. It reflects the extent to which the soil is suitable for growing crops. Values of 0 to 2 dS/m are safe for all crops; yields of very sensitive crops are affected between 2 to 4 dS/m; many crops are affected between 4 and 8 dS/m; while only tolerant crops grow reasonably well above that level. I.e. Barley (*Hordeum vulgare*) upper tolerable limit is 18 dS/m and Wheat (*Triticum aestivum*) is 13.0 dS/m [14]. In the Table 1 the results have shown that the soil salinity is safe and suitable to grow wheat and barley cereals as well as for all crops.

Total nitrogen analysis measures N in all organic and inorganic forms. The organic fraction constitutes the majority of total N in soils (usually >95%). It is composed mostly of plant and microbial remains, in variable composition. The inorganic phase of soil N is composed of ammonium (NH₄), nitrate (NO₃), and-very little though-nitrite (NO₂) forms. Environmental (temperature and moisture) and agronomic management (fertilization, cropping, etc.) factors influence its dynamic relationship with the organic fractions and also within the inorganic forms [14]. Only 1 to 4 percent of this total N becomes plant-available (converts via microbial activity from organic form to inorganic form) during a growing season [18]. As shown from the result the content of Total nitrogen decline from 0-20cm to 20-40cm depth, this is directly colerated with the soil organic matter. Soil organic matter (OM) has a major influence on soil aggregation, nutrient reserve and its availability, moisture retention, and biological activity. As soil test interpretation guide [18], soil OM increases so does CEC, soil total N content, and other soil properties such as water-holding capacity and

microbiological activity increases parallel. The result on Table 2 supports by soil interpretation guide that as the contents of organic carbon increases so does total nitrogen. Sulfur (S) exists in soil and soil solution mainly as the sulfate ($\text{SO}_4\text{-S}$) and Plants absorb sulfur in this form. Its level categories are low in

treatment three and medium for 0-500 m & 500-1500 m treatments. Along with N and P, potassium (K) is also of vital importance in crop production. It has categorized that medium content of potassium in all treatments.

Table 2. CEC, Organic carbon, Total nitrogen, S-SO_4^{2-} , Phosphorus and potassium.

Location one, around Abyssinia cement factory			Location Two, around Mugher cement factory					
Harvested crop	Parameters	Soil depths	mean \pm SD			mean \pm SD		
			Distance from the factory			Distance from the factory		
			0-500m	500-1500m	\approx 4000m	0-500m	500-1500m	\approx 4000m
barley	CEC	0-20cm	30.06 \pm 4.24a	31.39 \pm 1.24a	17.58 \pm 0.00b	40.30 \pm 8.71a	39.69 \pm 2.31a	31.50 \pm 0.00b
		20-40cm	30.99 \pm 5.02a	31.45 \pm 0.84a	19.78 \pm 0.00a	38.71 \pm 5.63a	39.13 \pm 4.55a	36.32 \pm 0.00a
	Oc (g/kg)	0-20cm	20.36 \pm 8.10a	20.92 \pm 1.76a	17.66 \pm 0.00a	9.07 \pm 3.74a	18.66 \pm 4.03a	35.52 \pm 0.00a
		20-40cm	19.19 \pm 6.80a	19.00 \pm 0.77a	17.19 \pm 0.00a	8.99 \pm 4.82a	15.43 \pm 5.12b	27.92 \pm 0.00b
	TN (g/kg)	0-20cm	1.72 \pm 0.69a	1.84 \pm 0.14a	1.68 \pm 0.00a	0.64 \pm 0.32a	1.46 \pm 0.28a	2.74 \pm 0.00a
		20-40cm	1.63 \pm 0.58b	1.71 \pm 0.11b	1.54 \pm 0.00b	0.65 \pm 0.41a	1.32 \pm 0.39b	2.75 \pm 0.00a
	S-SO_4^{2-} (mg kg $^{-1}$)	0-20cm	7.39 \pm 1.15a	9.29 \pm 2.74a	4.66 \pm 0.00a	4.08 \pm 0.99a	5.86 \pm 1.81a	6.83 \pm 0.00a
		20-40cm	5.24 \pm 1.21b	8.35 \pm 2.48b	3.32 \pm 0.00b	3.14 \pm 1.22b	4.24 \pm 1.98b	5.89 \pm 0.00b
	P (mg kg $^{-1}$)	0-20cm	19.45 \pm 4.35a	11.22 \pm 0.34a	5.58 \pm 0.00a	25.25 \pm 17.36b	51.15 \pm 14.17a	57.21 \pm 0.00a
		20-40cm	17.36 \pm 7.76b	10.44 \pm 2.76a	5.16 \pm 0.00a	24.56 \pm 16.85c	49.33 \pm 19.22b	120.39 \pm 0.00a
	K (cmol kg $^{-1}$)	0-20cm	0.64 \pm 0.05a	0.62 \pm 0.04a	0.53 \pm 0.00a	0.69 \pm 0.10a	0.68 \pm 0.04a	0.76 \pm 0.00a
		20-40cm	0.62 \pm 0.04a	0.65 \pm 0.07a	0.53 \pm 0.00a	0.60 \pm 0.06b	0.66 \pm 0.05a	0.86 \pm 0.00b

The significance difference between soil depths of CEC, Oc, TN, S, P and K at $p < 0.05$ are indicated with 'a' and 'b'.

4. Conclusions

According to soil interpretation guide line, the major nutrient status (i.e. phosphorus, nitrogen, organic matter and potassium) are medium to high category. The soil physic-chemical properties status, at $P < 0.05$ have shown significance difference between distances from the factories however no significance difference can occurs among soil depths. This might be due to the cement dust that changes the nutrient status of the top soil. The raw materials for cement productions (Limestone, clay, pumice, sandstone, gypsum, imported furnace oil and Kraft paper) might contribute to change soil physic-chemical properties of the top soil. Therefore, the factories should be subject to mandatory monitor and control the cement dust not to be polluting the agricultural fields and environment as well.

Conflict of Interest

The authors have not declared any conflict of interest.

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