Pollution Effect and Effluent Discharge on Soil Physico-chemical Properties Around Cement Factories

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Abstract: The different research finding has stated that the cement factory dust particulate matter has a negative effect on soil health, a significant source of heavy metal toxicity, and crop yield reductions. In this study, two cement factories' pollution effect and effluent discharge implication studies were conducted. seventy soil samples at different distances from the factory (0-750m, 750-2000m & 2000m-3000m), and effluent samples were collected and analyzed at Holeta Soil, plant and Water analysis Laboratory. Heavy Metals and major physico-chemical properties (TN, Oc, K, P, pH, Moisture, soil texture, Bulk density, SO_4-S, and Cation exchange capacity) were analyzed following the standard procedures. The content of heavy metals; Cu, Cr, Mn, Cd, Fe, Pb, As, and Zn were executed using AAS. One-way ANOVA subjected to compare the mean values of each parameter regardless of distance from the factories with SPSS statistical software. Soil pH is an excellent indicator of the suitability of soil for plant growth and crop productivity. For most crops pH of 6 to 7.5 is optimal, this research finding showed that the soil pH is neutral to moderately alkaline soil pH. The normal soil pH in the study areas are generally acidic, due to the continuous deposition of cement dust, soil pH was found slightly alkaline near the cement plants. The higher values of electrical conductivity and bulk density were also noticed near the cement plants. However, lower values of soil moisture content, soil organic carbon, and total nitrogen content were found compared to far from the factory. Heavy metals levels from factory effluent, Mugher location, of Cu, Mn and Cr are above the permissible limit set by FAO, not recommended for irrigation and cereal production activities. The effect of cement dust deposition on soil is greater in areas nearer to the cement plants. This trend of soil physic-chemical properties change, may adversely affect the area and lead to multiple effects on the flora, fauna and socio-economy of the area. The factory therefore should be monitor and control the cement dust and effluent discharge before released to the environment.

Key-words: Particulate matter; Effluent discharge; physic-chemical properties

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1. Introduction

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 industries and coupled with deforestation of natural forest. In comparison to the effect of gaseous pollutants on the air quality, little attention is given to the effect of particulate pollutants on soil, crop and vegetation properties [1, 2]. Globally, the problem of environmental pollution due to heavy metals has been a concern in most town leads to geoaccumulation, bioaccumulation and biomagnifications in ecosystem [2].

They are different sources of heavy metals in agricultural fields and corresponding crops; its availability to plants is due to mining activities, industrial exhausts & effluents, atmospheric depositions, waste disposals and agro-chemicals [3-6]. Metals 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 Fe and MnO_2 that, in turn, have an intense influence on soil geochemistry [7]. Metals are also present in the organic fraction, frequently as bound forms, with some metal recycling occurring as a result of organic matter decomposition. The aqueous phase provides a mobile medium for chemical reactions, metal transfer and circulation through the soil, to organisms, and also to the aquatic environment. The most important factors which affect metals mobility are pH, sorbent nature, presence and concentration of organic and inorganic ligands, including humic and fulvic acids, root exudates and nutrients.

The contamination of soil by heavy metals can be problematic on several levels because difficult to degrade biologically, poses risks to humans and animals through ingestion of bio-accumulated toxic metals plants from contaminated soil [8]. These heavy metals may adversely affect soil ecology, agricultural production and will ultimately harm to health of living organism by food chain. More detailed analyses showed that chemical properties of metals in soil and their retention in the solid phase of soil is affected by pH, quantity of the metal, cation-exchange capacity, content of organic matter and mineralogy of soil. Changes in chemical properties of soils affect concentration of free metals and result in changes in their availability for plants. With increasing pH, content of organic matter and clay the solubility of most metals decreases due to their increased adsorption. The decreased availability of metals is affected by higher adsorption and precipitation in alkaline and neutral environments [9].

Many research investigated the influence of the cement dust deposition on soil properties, plant growth and a contamination source of heavy metals [10-16]. The dust deposition from cement factory influenced by wind velocity, particle size, and stack fumes. Among the metals especially recognized in environmental studies on emission from cement plants to have toxic effect on soil are arsenic, cadmium, lead, mercury, thallium, aluminum, beryllium, chromium, copper, manganese, nickel and zinc [16]. This research therefore initiated to investigate the changes in soil physico-chemical properties due to pollutants and factory wastes from cement factories.

2. Materials and Methods

Description of the study areas

Two study areas were selected; The first study area is in Mugher, around Mugher cement factory, which is located 90 km North West of Addis Ababa. The second study area is in Chancho, around Abyssinia cement factory, which is located 40 km north of Addis Ababa. The three experimental categories, distance from the factories (0-750m, 750-2000m & 2000m-3000m), were chosen. The treatment selection was carried out based on proximity to the study areas and the probabilities of prevalence of dust particles depositions.

Soil sample collections

About one kilogram soil samples from 0-20 cm soil depth collected following Random sampling techniques using Auger. Core samplers used for bulk density sampling separately. 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 soil and plant analysis laboratory for preparation and further analysis.

Effluent sample collections

The effluent samples were collected from Mugher site for heavy metals, pH and electric conductivity determination. Manually, eight grab sample taken at equally spaced time (30 minute) intervals over the sampling period combine in equal volumes [17] with three replications. The collected samples stored in container which soaked overnight with 5% HNO_3 followed by rinsed with distilled water prior to pretreatment.

Soil sample preparations and pretreatments

The collected field 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 opening) stainless steel sieve [18, 19].

3. Soil Physico-Chemical Analysis Procedures

Moisture

Five gram soil sample were weighed to moisture can with 0.001 g accuracy, was dried overnight at 105°C, cooled in desiccator and weighed. The moisture content in wt % (w/w) is calculated by [18]:

$$Moisture\ (wt\ \%) = \frac{fresh\ weight(g) - dry\ weight(g)}{dry\ weight(g)} * 100$$

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/cm^3 calculated as [20].

$BD = \frac{Wtsc*100}{V}$, where: V = volume of soil core ($\pi r^2 h$), Wtsc= Dried weight of sample.

Electrical conductivity

20 g soil sample were weighed into a beaker, 20 mL water added, stirred thoroughly, and allow the suspension to stand for 20 min. The conductivity cell inserted to the suspension and read the electrical conductivity [21]. The result reported is in µS/cm.

pH

The pH of soil sample was measured potentiometrically in the suspension of a 1(20g):2(40ml) soil liquid mixtures. 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.

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 38% sodium hydroxide; the distillate (evolved ammonia) was trapped in 1% boric acid and titrated with standard acid with 0.01 *M* HCl [18].

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 with ferrous sulphate and reported as g/kg [18].

Phosphorus soluble in sodium bicarbonate

(*Extraction according to Olsen et al*.)

The soil 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 [19].

Potassium and Cation Exchange Capacity

Ammonium acetate methods were used to extract exchangeable potassium. 5g soil sample weighed in 100 mL beaker and socked overnight by 50 mL ammonium acetate. The sample 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 [22].

Heavy metals in soils

NH_4HCO_3–DTPA, HNO_3-$HClO_4$ for available and total heavy metals analysis were followed respectively **[23]**

4. Heavy Metals in Effluents

Nitric Acid digestions were followed: 100 mL sample measured to a beaker and 5 mL conc. HNO_3 poured to it. The mixture were then boiled and evaporated on hot plate upto 20 mL. After digestion completed, it was transferred to 100 mL volumetric flasks [24]. The pH and Electric conductivity were determined directly with pH meter and conductivity meter respectively. The solution kept in refrigerator for heavy metal analysis.

Table 1: pH, EC and BD

Experimental design	pH	EC (µS/cm)	BD (g/cm^3)	Moisture (%)
0--750M	**8.010**	**131.678**	**1.335**	**10.588**
750-2000M	**7.185**	**87.965**	**1.266**	**12.653**
2000-3000M	**6.490**	**75.667**	**1.250**	**13.335**

Table 2: CEC, Organic carbon, Total nitrogen, $S\text{-}SO_4^{-2}$, Phosphorus and potassium

Experimental design	**CEC (cmol kg^{-1})**	**Corg. (g/kg)**	**Ntot. (g/kg)**	**$S\text{-}SO^{-2}{}_4$ (ppm)**	**P (ppm)**	**K (cmol kg^{-1})**
0--750M	33.803	15.005	1.233	6.003	20.188	0.638
750-2000M	34.905	23.180	1.948	8.538	46.723	0.660
2000-3000M	26.405	24.468	2.245	5.963	25.910	0.615

Table 3: Available HMs in soil extracted with Ammonium Bicarbonate-DTPA

Experimental design	**Fe (ppm)**	**Mn (ppm)**	**Zn (ppm)**	**Cu (ppm)**	**Cr (ppm)**	**Pb (ppm)**
0--750M	308.080	6.958	16.105	3.733	2.755	1.125
750-2000M	489.333	20.788	26.103	4.010	1.008	0.973
2000-3000M	547.583	17.238	24.338	3.935	1.063	0.565

Table 4: Total heavy metals digested with $HNO_3\text{-}HClO_4$

Experimental design	**Fe (%)**	**Mn (ppm)**	**Zn (ppm)**	**Cu (ppm)**	**Cr (ppm)**	**Pb (ppm)**
0--750M	67.823	1359.405	107.500	59.200	19.930	13.440
750-2000M	55.970	1467.405	110.835	57.638	16.373	10.218
2000-3000M	35.013	680.443	68.020	41.710	10.478	4.735

Table 5: pH, EC and heavy metals in effluent samples

Effluent Type	**pH**	**EC**	**Fe**	**Mn**	**Zn**	**Cu**	**Cr**	**Pb**
Factory	7.68	355	1860	2.59	1.74	0.59	0.12	0.03
Toilet	6.82	991	93.33	0.151	0.012	0.019	0.007	ND
(FAO)	***6.5-8.4***	***700***	**5.00**	**2.00**	**2**	**0.2**	**0.1**	**5.0**
Critical limits as described by FAO, (1985), ND = Not detected								

5. Results and discussion

The normal soil pH in the study areas are generally acidic, soil pH near to cement plant found slightly alkaline. The higher values electrical conductivity and bulk density were also noticed near to the cement plants. However, lower values of soil moisture content were found near to the factory compared to far from the factory. 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. Salinity 0 to 200 μS/cm are safe for all crops; Very sensitive crops are affected between 200 to 400 μS/cm; many crops are affected between 400 and 800 μS/cm; while only tolerant crops grow reasonably well above that level. The results have shown that the soil salinity is safe and suitable to grow crops in general.Total nitrogen determination measures nitogen 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 (NH_4), nitrate (NO_3), and-very little though-nitrite (NO_2) 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 [20]. Only one to four percent of this total N becomes plant-available converts via microbial activity from organic form to inorganic form during a growing season [27].

Soil organic matter (OM) has a major influence on soil aggregation, nutrient reserve and its availability, moisture retention, and biological activity. Refering soil test interpretation guide [27], soil organic matter increases so does CEC, soil total N content, and other soil properties such as water-holding capacity and microbiological activity. Sulfur (S) exists in soil and soil solution mainly as the sulfate (SO_4-S) and Plants absorb sulfur in sulfate form. Along with N and P, potassium (K) is also of vital importance in crop production. It is widely accepted that determining the total heavy metals in a soil is neither sufficient to understand their relative mobility and ecological availability as contaminants nor particularly useful as a tool to estimate potential risks. The level of cadmium and arsenic were not detected in any of sample in the study area. It is well known that metals solubility in soils mainly depends on soil pH, organic C, CEC, and clay contents [25, 26]. 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.Factory and toilet effluents sources from Mugher cement plant discharged to the agricultural fields. The high concentration of heavy metals found in the factory effluent as compared to toilet effluent. The Fe, Cu, Mn and Cr level of factory effluent are upper the permissible limit referring the FAO standard. Cadmium (Cd) and Arsenic (As) were not detected in both effluent samples analyzed in the study area. In addition to Cadmium (Cd) and Arsenic (As), lead (Pb) also was not detected in toilet effluent sample. The conductivity of toilet effluent obtained higher than factory effluent and recorded above the permissible limit.

6. Conclusions

The normal soil pH in the study areas are generally acidic, due to the continuous deposition of cement dust, soil pH was found slightly alkaline near the cement plants. The higher values electrical conductivity and bulk density were also noticed near to the cement plants. Due to the cementation of dust particles over the agricultural field, the soil pH change to alkaline and poses to limit available nutrients to the plant. The cementation can also affect the moisture and bulk density this leads to unplougn and difficult prepare the land. Heavy metals content (Cu, Mn and Cr) from factory effluent are above the permissible limit set by FAO, not recommended for irrigation and cereal crop production. This trend of soil physic-chemical properties change, may adversely affect the area and leads to multiple effects on flora, fauna and socio-economy of the area. The factory therefore should be monitor and control the emanates cement dust and effluent discharge before released to the environment.

Statistical Analysis

Statistical analyses were carried out using SPSS software, version 20. One way ANOVA, descriptive statics, subjected for comparing the mean concentration of soils. Significance difference among treatments indicated for each parameter at $p < 0.05$ and the results were reported as mean.

Conflict of Interests

The authors have not declared any conflict of interests.

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References

[1]. Muhammad, Z.I; Muhammad, S. (2001). Periodical effect of cement dust pollution on the growth of some plant species. Turk J. Bot, 25, 19-24

[2]. Princewill, C. Ogbonna; Adanma, N.N. (2011). Metal concentration in soil and plants in abandoned cement factory. Int Conference on Biotechnology and Environment Management IPCBEE, 18, Singapore

[3]. Al-Lahham O, El-Assi N M and Fayyad M. (2003). Impact of treated waste water irrigation on quality, attributes and contamination of Tomato fruit, Agric. Water Manage., 61(1), 51-62. p

[4]. Asdeo A and Loonker S. (2011). A comparative analysis of trace metals in vegetables, Res. J. Environ. Toxicol., 5(2), 125-132.

[5]. Mingorance M D, Valdes B and Oliva Rossini S. (2007). Strategies of heavy metal uptake by plants growing under industrial emission, Environ. Int., 33(4), 514-520.

[6]. Mohammed NK and Khamis FO. (2012). Assessment of heavy metal contamination in vegetables consumed in Zanzibars, Sci. Res., 4(8), 588-594.

[7]. Gadd, J.M. (2008). Transformation and mobilization of metals, metalloids, and radionuclides by microorganisms. In: A. Violante, P.M. Huang, G.M. Gadd. (eds). Biophysico- Chemical Processes of Metals and Metalloids in Soil Environments. Wiley-Jupac Series, Vol 1 John Wiley & Sons, Hoboken, NY pp: 53-96.

[8]. Turner, A.H. (2009). Urban Agriculture and Soil Contamination: An Introduction to Urban Gardening, Environmental Finance Centre, EPA Region 5, University of Louisville, pp. 1–17.

[9].Morel J.L. (1997): Bioavailability of trace elements to terrestrial plants. Soil Ecotoxicology: 141–176

[10]. Kalafatoglu, E., Örs, N., Özdemir, S. S. and Munlafalioglu, I. (2001). "Trace element emissions from some cement plants in Turkey", Water, Air and Soil Pollution, 129: 91-100

[11]. Princewill, C. Ogbonna; Adanma, N.N. (2011). Metal concentration in soil and plants in abandoned cement factory. Int Conference on Biotechnology and Environment Management IPCBEE, 18, Singapore

[12]. Muhammad, Z.I; Muhammad, S. (2001). Periodical effect of cement dust pollution on the growth of some plant species. Turk J. Bot, 25, 19-24.

[13]. Emmanuel Olubunmi Fagbote and Edward Olorunsola Olanipekun. (2010). Evaluation of the status of heavy metal pollution of soil and plant (Chromolaena odorata) of Agbabu Bitumen deposit area, Nigeria. American-Eurasian Journal of Scientific Research, 5(4), 241-248.

[14]. Ahiamadjie, H; Adukpo, O.K. (2010). Determination of the elemental contents in soils around diamond cement factory, Aflao. Research Journal of Environmental and Earth Sciences, 3(1), 46-50.

[15]. Al-Oud, S.S; Nadeem, M.E.A; Al-Shbel, B.H. (2011). Distribution of heavy metals in soils and plants around a cement factory in Riyadh city, central of Saudi arabia. American-Eurasian J. Agric. & Environ. Sci, 11(2), 183-191.

[16]. Addo, M.A; Darko, E.O. (2012). Evaluation of heavy metals contamination of soil and vegetation in the vicinity of a cement factory in the Volta region, Ghana. Int. J. Science and Technology, 2, 1.

[17]. Ontario Ministry of the Environment and Climate Change (OMECC), (2016). Protocol for the Sampling and Analysis of Industrial/Municipal wastewater, Version: 2.0

[18]. Reeuwijk, LP van (2002). Technical paper in procedures in soil analysis. 6th edition.

[19]. Virgina Cooperative Extension program. (2011). Soil testing laboratory procedures: 452- 881

[20]. George Estefan, R.S. and John Ryan (2013). Method of soil, plant and water analysis, 3rd edition.

[21]. Bonton .Jr. (2001). Laboratory guide for conducting soil tests and plant analysis.

[22]. Black, C.A. (Ed) (1965). Determination of exchangeable Ca, Ma, K, Na, Mn and effective cations exchange capacity in soil. Methods of soil analysis agro. No. 9 part 2 Amer. Soc. Agronomy, Madison, Wisconsin

[23]. Benton jones, j. jr. (1999). Soil analysis hand book of reference methods 139-145

[24]. Maiti, S.K. (2004). Handbook of Methods in Environmental Studies Water and Wastewater Analysis, vol.1

[25]. Hough, R.L., S.D. Young and N.M.G. Crout (2003). Modeling of Cd, Cu, Ni, Pb and Zn uptake by winter wheat and forage maize, from a sewage disposal form. Soil Use Manage.19:19- 27.

[26]. Walker, D.J., R. Clemente, A. Roig and M.P. Bernal. (2003). The effects of soil amendments on heavy metal bioavailability in two contaminated Mediterranean soils. Environ. Pollut. 22(2):303-312.

[27]. Donald A. Horneck, Dan M. Sullivan, Jim S. Owen, and John M. Hart (2011). Soil Test Interpretation Guide