GLOBAL JOURNAL OF ENGINEERING, DESIGN & TECHNOLOGY
(Published By: Global Institute for Research & Education)
www.gifre.org

COMPARATIVE STUDY OF COMPOSTED AND UNCOMPOSTED DIGESTATES, CHICKEN MANURE AND COW DUNG AS FERTILIZERS AND THEIR EFFECTS ON SOIL PROPERTIES

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Abstract

Digestate was developed from domestic municipal organic waste as an effort to control or manage waste problems and also provide alternate source of fertilizer for farmers to improve soil fertility. The digestate was composted using three methods namely windrow, co-composting and vermi-composting. The digestates were compared with chicken manure and cow dung in an application on soil. Soil parameters including N, P, K and CEC needed for plant growth were determined. The final soil analysis showed varied improvements in N, P, K and CEC. The vermi compost treatment showed the best soil improvement treatment in terms of soil N (0.18 % and 0.21 % for 0-15 cm and 15-30 cm soil depths respectively), both K and CEC in the 15-30 cm soil depth (0.63 cmol/kg and 13.74 cmol/kg respectively) and second best for both P and CEC in the top 15 cm soil depth (0.083 cmol/kg and 9.34 cmol/kg respectively).

Keywords: Digestates, Chicken Manure, Cow Dung, Windrow, Co-compost.

1. Introduction

Waste generation in Ghana is increasing due to the increase in population and urbanization of cities with a corresponding problem with management of large volumes of waste generated. The use of organic components of waste as fertilizer is a step in the right direction to reduce the problem of waste disposal. Continuous use of cropping land and the problem of harsh environmental condition have contributed to the fast decline of soil fertility (Henao and Baanante, 1999). Inorganic fertilizers are expensive and problematic when applied in excess than the organic fertilizers and hence the need for more sources of organic fertilizers.Regular use of inorganic fertilizers causes long-term depletion of organic matter, soil compaction, and degradation of overall soil quality (Sullivan, 2004). According to Gupta and Gupta (2011), the use of organic manure is better for quality and yield of crops and increase rapidly since the start of green revolution. Bermejo et al. (2010), researched on the use of dry and wet digestates from biogas plant as fertilizers in crop production and the digestates showed improvements in soil and plant qualities. They investigated the effect of wet and dry digestates in direct comparison to conventional fertilizers such as mineral fertilizer (Calcium ammonium nitrate), liquid manure, and farmyard manure in a field experiment carried out within a randomised complete block design.Anaerobic fermentation of digestate reduces the C:N ratio, increases the stability of organic matter and the content of NH_4^+ resulting in a product with a high content of directly available N (Gutser et al, 2005).

The high cost of inorganic fertilizers and low levels of income of farmers have led to the search for alternate fertilizer sources which are cheaper and hence the reliance on organic manure. According to Agyarko and Adomako (2006), the cheapness and effectiveness of organic manure are the reasons behind their use as fertilizers. Organic manure adds valuable organic matter to the soil, has slow release of nutrients, supplying secondary and trace elements which are occasionally lacking in conventional farming systems that rely on primary or artificial sources of fertilizer(Tilman, 1998; Bailey, 2002). A comparative study ofcomposted and uncomposteddigestates, chicken manure and cow dung as fertilizers and their effects on soil properties would help find solutions to some wastes and also know which waste source offers the best soil improvement qualities.

The aim of the study was to determine the effects of composted, uncomposted dry fermented digestate, chicken manure and cow dung on soil properties and the specific objectives were,
To determine and compare the effects of these organic fertilizers on soil N, P, K and determine and compare the effects of these organic fertilizers on soil cation exchange capacity (CEC).

2. Materials and Methods

The study was conducted at the Agricultural Engineering farm on the Kwame Nkrumah University of Science and Technology campus.

Chicken and Cow dung manures were procured from the Animal Science Farm of the Faculty of Agriculture of KNUST. The compost manure and the dry fermented digestates wereobtained from a colleague‘s project work, where waste from a dump site was undertaken through a dry fermentation process and composted using three composting methods namely windrow, co-composting and vermi-composting.

The experiment was designed using the Randomised Complete Block Design was used. Three blocks with seven plots each of 2 m x 1 m size per plot were constructed and amounts of manure corresponding to 90 kg of N / ha from poultry manure (4 t / ha), cow dung manure (7.5 t / ha), 3 types of dry fermented digestate composted (17 t / ha each), dry fermented digestateuncomposted (17 t / ha) or no treatment (as a control) was applied to each plot per block in a randomized form.

Treatments were as follows:

T_1 – Control
T_2 – Chicken Manure
T_3 – Cow Dung
T_4 – Uncomposted Dry Fermented Digestate
T_5 – Windrow Composted Dry Fermented Digestate
T_6 – Co-composted Dry Fermented Digestate
T_7 – Vermi-composted Dry Fermented Digestate

2.1 Land Preparation

The land was ploughed and harrowed with a tractor. The Blocks and the Plots were done across the gentle slope of the land. The weeds, mostly guinea grass were removed during the preparation of the beds. The beds were heaped 15cm off the ground.

2.2 Initial Sampling of Organic Manures and Soil and Preparation for Laboratory analysis

The chicken manure was collected from one of the battery cages of the poultry section of the Animal Science Department Farm of the Faculty of Agriculture of KNUST in a polythene bag, mixed thoroughly and 1 kg of the droppings was taken for laboratory analysis. The cow dung was collected from the livestock section of the farm from the kraal in a polythene bag, mixed thoroughly and 1 kg taken for laboratory anlysis. The anlysis were done on the following parameters: pH, organic matter content, organic carbon, nitrogen, phosphorus, potassium, magnesium, calcium, sodium, aluminium and hydrogen. One kilogrameach of the uncomposted digestate and the composted digestates were also taken for laboratory analysis for the same parameters.

A 15 cm hand auger was used to sample soil from the 0-15 cm and 15-30 cm soil depths from each plot and the soils from the same depths were mixed together in a bucket and 2 kgeach was taken, put in plastic bags labelled 0–15 cm and 15-30 cm respectively and sealed for laboratory anlysis for the same parameters as the manures in addition to bulk density and particle size distribution.The bulk density was found by using the core sampler method, the pH was by the electrometric method, the N was by the Micro Kjeldahl’s method, the P by the BrayP1 extraction method, the K, Na, Ca and Mg by the Ammonium acetate extraction method, Al and H were by the Potassium chlorate extraction method and the particle sizedistribution by the hydrometer method.

2.3 Application of Treatments

The chicken manure, cow dung and the uncomposted dry fermented digestate were applied after initial soil samples had been taken for laboratory analysis. In order to apply 90 kg of N per hectare, 1 kg of the chicken manure was applied as a treatment per plot, 1.5 kg of cow dung was applied per plot and 3.5 kg of the uncomposted and 3.5 kg each of the composted dry fermented digestates (windrow, co-compost and vermi-compost) were applied per plot for 3 months. A chemical balance was used to weigh the fertilizers. The measured amounts of the various fertilizers were spread on the the plots and a hoe was used to incorporate them into the soil. The soils on the various plots were turned over when the surfaces became hard to allow for aeration and infiltration of water.The plots were watered three times in a week with 20 litres of water per plot.

2.4 Weed Control

Weeds that appeared on the beds were controlled by weeding with a hoe and cutlass as well as those between the plots at 2 weeks interval to prevent any reduction of nutrients and also reduce any effects that the weeds might have on the soil. The weeds were cleared away from the plots to prevent them decomposing on the plots.

2.5 Final Sampling of Soil and Preparation for Laboratory Analysis

The final soil sampling was similar to the initial but here, two points were sampled per plot and the soils mixed thoroughly before a final sample was taken for the laboratory analysis. The two points were selected by dividing the plot into three sections and using the middle of the two dividing lines as the sampling points. The two points were sampled for the 0-15 cm and 15-30 cm sections of the soil horizons or profile. The two samples for each plot (0-15 cm and 15-30 cm) were packaged in plastic bags and labelled appropriately. The samples were prepared as the initial samples and the same parameters determined as the initials. Samples for the bulk densities were taken for individual plots and determined as the initials were done.

3. Results and Discussions

Initial and final soil data of soil samples from each plot were generated by determining bulk density, particle size distribution, soil pH, organic matter content, N, P, K, Na, Ca, Mg, Al, and H ions.Cation exchange capacity (CEC) was calculated from the results of K, Ca, Mg and Na. The same parameters with exception of particle size distribution and bulk density were determined for the manures. The results were presented in tables and bar charts

3.1 Initial Soil and Manure Test and Analysis

Table 1: Initial Soil Test Results

SAMPLE	pH	N (%)	P(cmol/kg)	K(cmolkKg)	O.M (%)	O.C (%)
SOIL (0-15)	5.79	0.15	0.088	0.48	7.14	4.14
SOIL(15-30)	5.51	0.14	0.026	0.45	6.12	3.55

SAMPLE	Ca(cmol/kg)	Mg(cmol/kg)	Al(cmol/kg)	H(Cmol/Kg)	Na(cmol/kg)
SOIL(0-15)	3.40	1.00	0.20	4.40	0.30
SOIL(15-30)	4.00	0.40	0.20	4.40	0.94

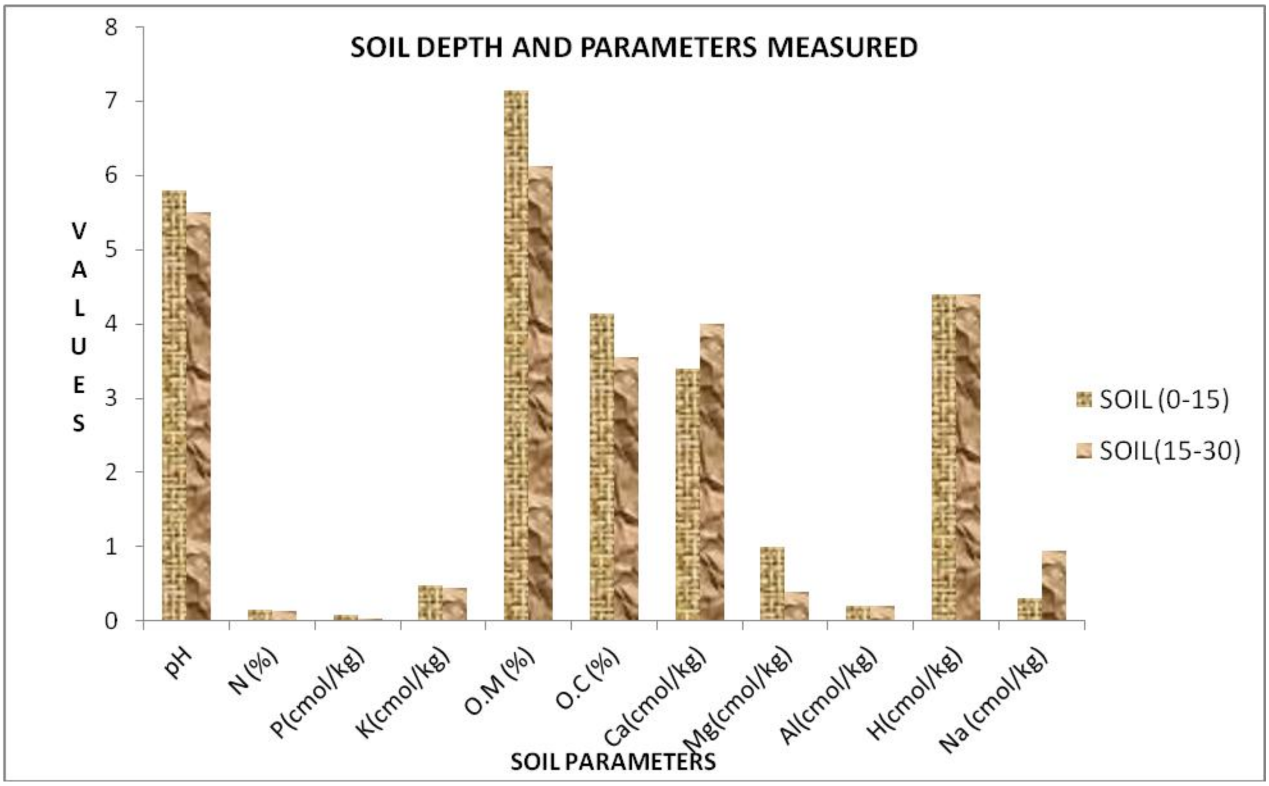

Figure 1: Initial Soil Test Results

3.1.1 Discussion of Initial Soil Test Results

Figure 1 characterises the soil conditions before the treatments were applied and in terms of pH, the soil was slightly acidic (5.79 and 5.59 for top 15 cm and 15-30 cm respectively) and from the results, most of the parameters measured for the top 15 cm depth of the soil had slightly higher values than the 15-30 cm depth of the soil except Ca and Na which were higher in the 15-30 cm depth (3.4 and 0.3 cmol/kg in top 15 cm and 4 and 0.94 cmol/kg in 15-30 cm respectively). Al and H did not vary with depth.

The cation exchange capacity (CEC) calculated from the elements K, Ca, Mg and Na for the 0-15 and 15-30 cm portions of the soil were 6.38 and 6.99 cmol/kg respectively which fall in the range of 5-30 cmol/kg for soils used in plant production (Cowan, 2008). The percentage saturations of the elements K, Ca, Mg and Na for the 0-15 cm and 15-30 cm portions of the soil are 7.52, 53.29, 15.67, 4.70 and 6.44, 57.22, 5.72, 13.45 respectively which are within the ranges for these elements in the soil except Na in the 15-30 cm portion.

The initial particle size distribution showed that the soil was sandy loam and the initial average bulk density was 1.01gcm^{-3} and this was good for plants growth.

Table 2: The Levels of Selected Parameters of Manure

SAMPLE	pH	N (%)	P (%)	K (%)	O.M (%)	O.C (%)
CHICKEN	8.92	2.80	2.05	5.69	58.68	34.03
COWDUNG	8.61	1.40	0.51	3.45	41.13	23.86
UNCOMPOSTED DIGESTATE	9.17	1.5	0.0001	0.0002	58.16	33.73
WINDROW COMPOST	8.46	2.03	0.0009	0.0017	53.17	30.84
CO-COMPOST	8.61	2.1	0.0004	0.0015	50.77	29.45
VERMI-COMPOST	7.96	1.93	0.0005	0.0013	44.4	25.75

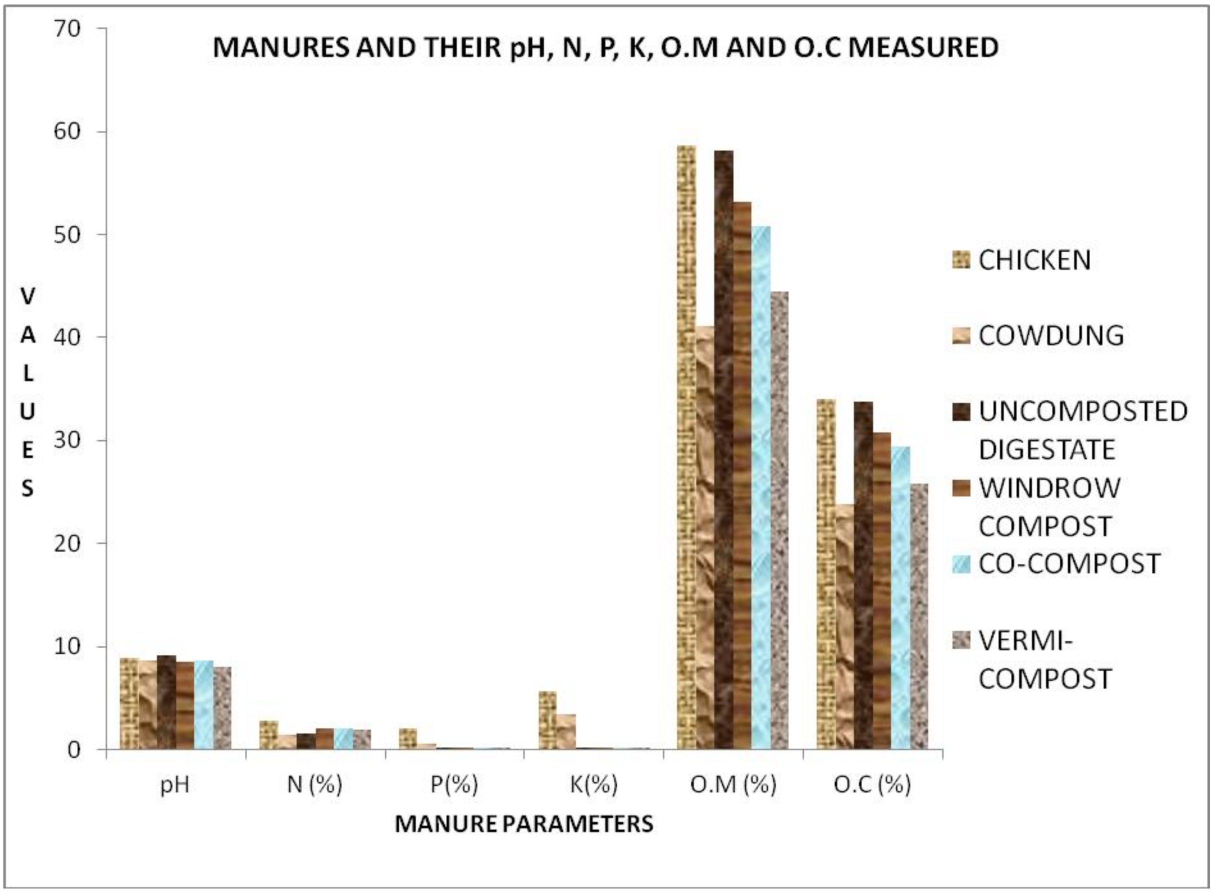

Figure 2: Manure Test Results

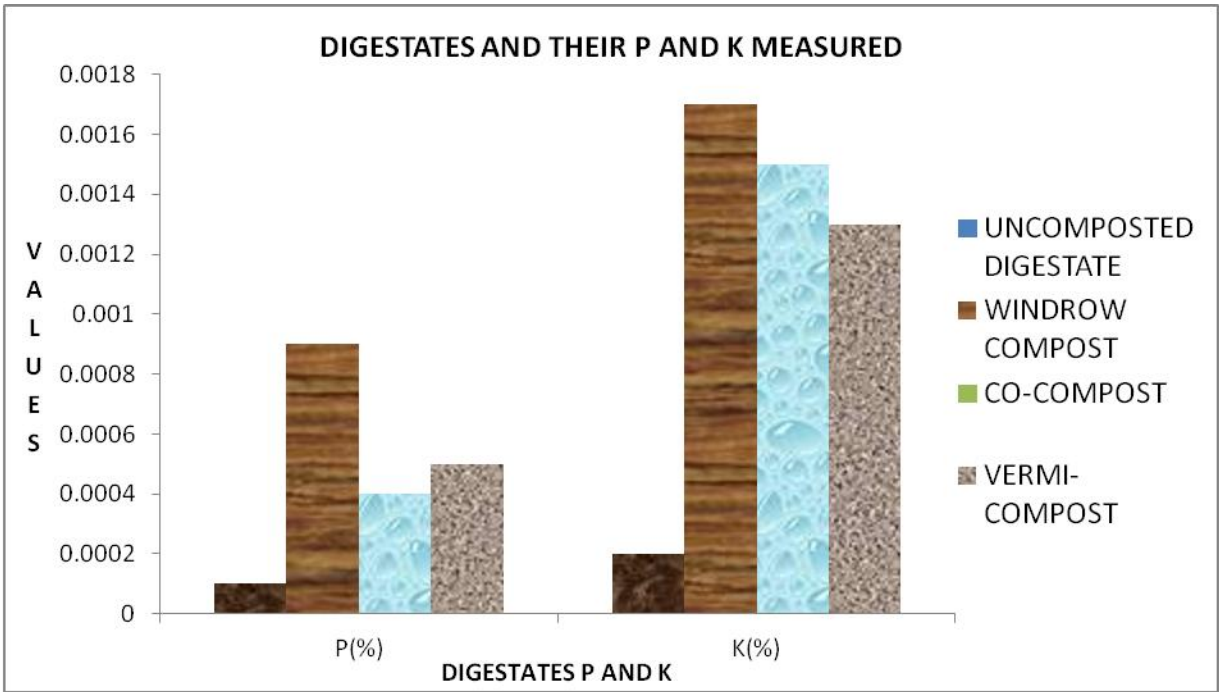

Figure 3: Digestate P and K

From figure 2, the pH of the manures were basic with the uncomposted digestate being the highest followed by chicken manure and then cow dung and co-compost which were the same and the vermi-compost being the least.

The nitrogen in the chicken manure was the highest followed by the composts in the order co-compost > windrow >vermi-compost >uncomposteddigestate> cow dung. All these were greater than that of the soil. The increase of N in the compost over the uncomposted was as a result of the composting as nitrifying bacteria during the process causemineralisation of N (Gale, 2005). Composting of organic residues permits the breakdown of the residues to occur without competition of micro organisms and higher plants for the mineral nitrogen and also reduces the C:N ratio of the resulting mass to a C:N value of less than 20:1.

The chicken manure had the highest P content followed by the cow dung with the digestates having negligible amount in the order: windrow compost > vermi compost > co-compost > uncomposted digestate. Potassium had similar trend in terms of its values recorded however the co-compost had higher potassium than the vermi compost.

A factor of 0.58 multiplied by the organic matter content gives the organic carbon. The laboratory analysis showed organic matter and carbon were highest in the chicken manure followed by the digestates in a decreasing order of uncomposted digestate > windrow compost > co-compost > vermicompost and this could be supported with the argument that the organic matter and organic carbon decreased with increasing faunal and chemical activities from the uncomposted digestate to the vermi-compost where earthworms were added and therefore the used up of carbon by fauna in breakdown activities. Cow dung recorded the least. The chicken manure and the uncomposted digestate had almost the same value as the difference between them was insignificant.

Table 3: Final Soil Samples Analysis

SAMPLE	BULK DENSITY	pH (0-15)	pH (15-30)	N (%) (0-15)	N (%) (15-30)	P (cmol/kg) (0-15)	P (cmol/kg) (15-30)
T1-Control	1.32	5.34 a	5.29 a	0.17 a	0.17 a	0.042 a	0.051 a
T2-Chkn	1.28	5.14 b	5.40 b	0.17 a	0.18 a	0.116 b	0.091 b
T3-Cow dung	1.27	5.48 c	5.26 a	0.14 b	0.15 b	0.081 cd	0.051 a
T4-Uncmpstd D.	1.33	5.43 cd	5.26 a	0.17 a	0.14 b	0.086 cd	0.088 bd
T5-Windrow C.	1.30	5.43 cd	5.45 b	0.17 a	0.17 a	0.086 cd	0.059 c
T6-Co-compost	1.30	5.39 ad	5.33 a	0.15 b	0.15 b	0.072 c	0.091 b

T7-vermi Comp.	1.32	5.55 e	5.53 c	0.18 a	0.21 d	0.088 d	0.083 d
CV	5.34	0.69	0.69	7.75	5.68	10.38	4.84
LSD		0.07	0.07	0.02	0.02	0.015	0.006
F RATIO (TREATMENT)	0.32ns	36.78*	24.07*	3.82*	17.51*	20.95*	85.69*
F RATIO (BLOCKS)	0.83ns	4.55*	0.34ns	0.21ns	3.45ns	0.40ns	1.98ns

* - Significant at 5% ns – Not Significant

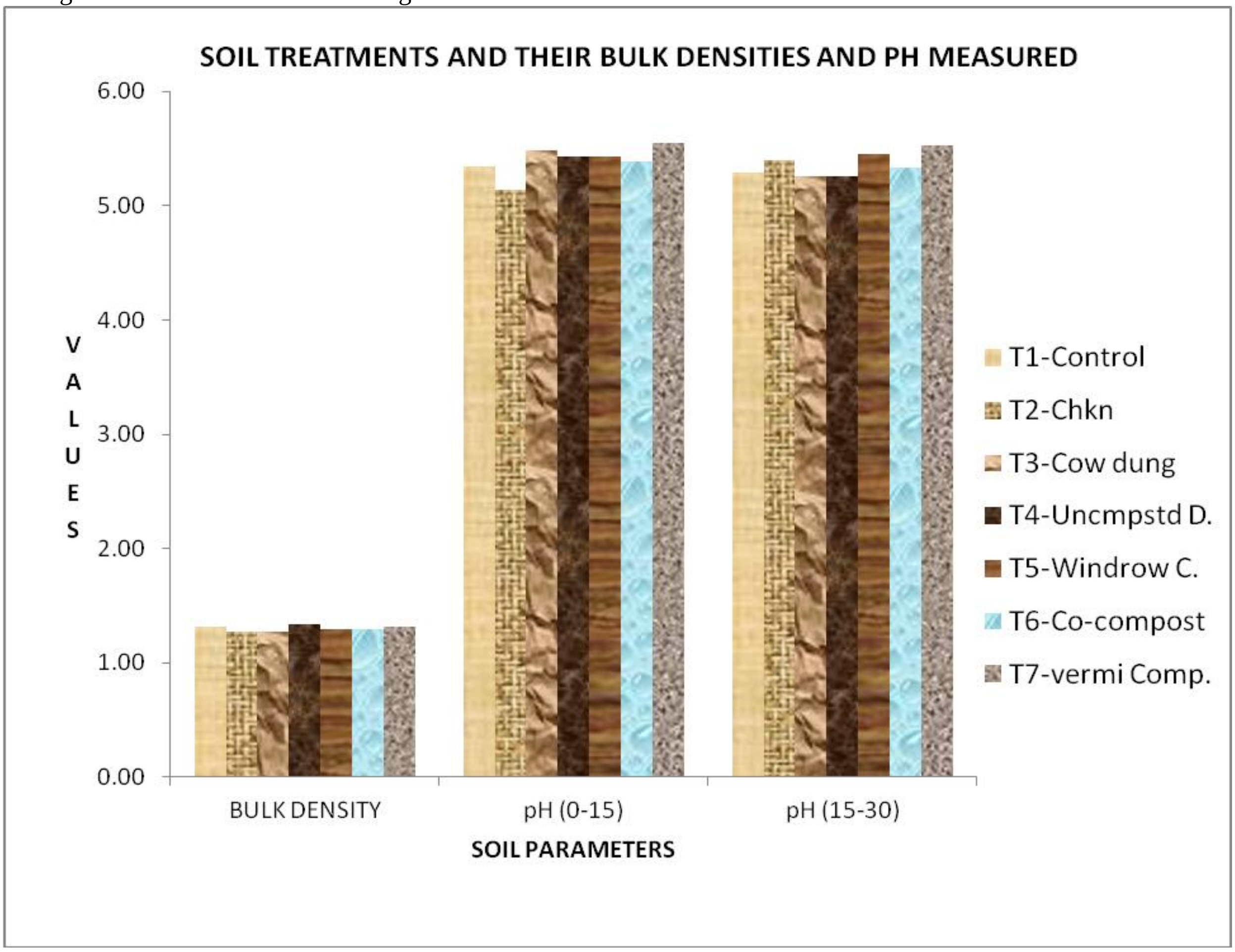

Figure 4: Final Soil Bulk Densities and pH

From table 3, the treatments did not affect the bulk densities of the soil.

The treatments affected the pH and thus were significant at P>0.05 with the final pH value reducing further than the initial samples making the soil more acidic except the vermi compost treatment for the 15-30 cm which increased (comparing tables 1 and 3). This increase in acidity could be attributed to the increase in exchangeable acidity from Al and H ions. Al ions could be attracted to the exchangeable sites or OH ions and release more H ions into the soils solution and Al ions could be difficult to remove from the exchangeable sites. Also, other cations could have exchanged H and more H ions could have been released from the exchangeable sites into soil solution and thereby increasing the pH as the final soil test results for Al and H ions recorded were higher than the initials except for the vermi compost treatment for the 15-30 cm. The treatments produced different values of pH in the soil except for the cow dung and uncomposted digestate treatments for the 15-30 cm portion of the soil which were the same (5.26).

The control and co-compost treatments for the top 15 cm soil depth were not different from each other and therefore had the same pH effect. Similarly, the cow dung, uncomposted digestate and the windrow compost treatments were not different from each other for the top 15 cm soil depth. The co-compost treatment was again not different from the uncomposted digestate and the windrow compost treatments for the top 15 cm soil depth. The chicken manure and vermi compost treatments had different pH effects from each other and from all others for top 15 cm soil depths. Comparatively, the chicken manure treatment produced the most acidic soil (5.14) for the top 15 cm portion of the soil.

For the 15-30 cm soil depth, the control, cow dung, uncomposted digestate and the co-compost were not different from each other and therefore had the same pH effect. Similarly the chicken manure and windrow compost treatments were not different from each other. The vermi compost treatment was different from all the other treatments. The control, cow dung, uncomposted digestate and the co-compost treatments produced acidic soils for the 15-30 cm depth (5.29, 5.26, 5.26 and 5.33 respectively) and the vermi compost treatment comparatively produced the least acidic soils for both depths (5.55). Vermi compost was the least basic manure (7.96) but eventually produced the least acidic soils whiles the other manures being more basic produced more acidic soils.

The treatments were significant at $P<0.05$ for N at both depths of the soil and thus were affected by the treatments whereas blocking did not affect the various treatments. The N levels in both depths increased except for co-compost and uncomposted digestate treatments for the top 15 cm and 15-30 cm respectively which remained the same and the cow dung treatment for the top 15 cm which reduced. The vermi compost produced the highest N of 18 cmol/kg and this was not different from those of the uncomposted digestate, the chicken manure and the control treatments for the top 15 cm andfor the 15-30 cm depth, the vermi compost treatment produced the highest N content of 0.21 cmol/kg. The exceptional increase in the N content of the vermi compost treated soil could be due to increased microbial populations (Maerere et al., 2000) from the introduction of earthworms in preparing the compost and this could have aided in the mineralization of N in the soil. Also, cow dung treated soil produced the least N content (0.14 cmol/kg) for the top 15 cm of the soil and this was not different from the co-compost (0.15 cmol/kg). The uncomposted digestate treated soil produced the least N content (0.14 cmol/kg)for the 15-30 cm soil depth and this was not different from cow dung and the co-compost treated soils (0.15 cmol/kg for both). This low N content from cow dung and uncomposted digestate treated soilswere due to the low N content in their respective manures compared to the others and this might have affected the microbial activities and the further mineralization of N.Co-compost treated soil produced low N content although compost manure had a moderate N content of 2.10 % and this could be attributed to a steady mineralisation of N from this treatment as it produced the same value of 0.15 cmol/kg in both depths of the soil. The high N content produced by the uncomposted digestate treated soil in the top 15 cm of the soil and the control treatment could be attributed to natural causes.

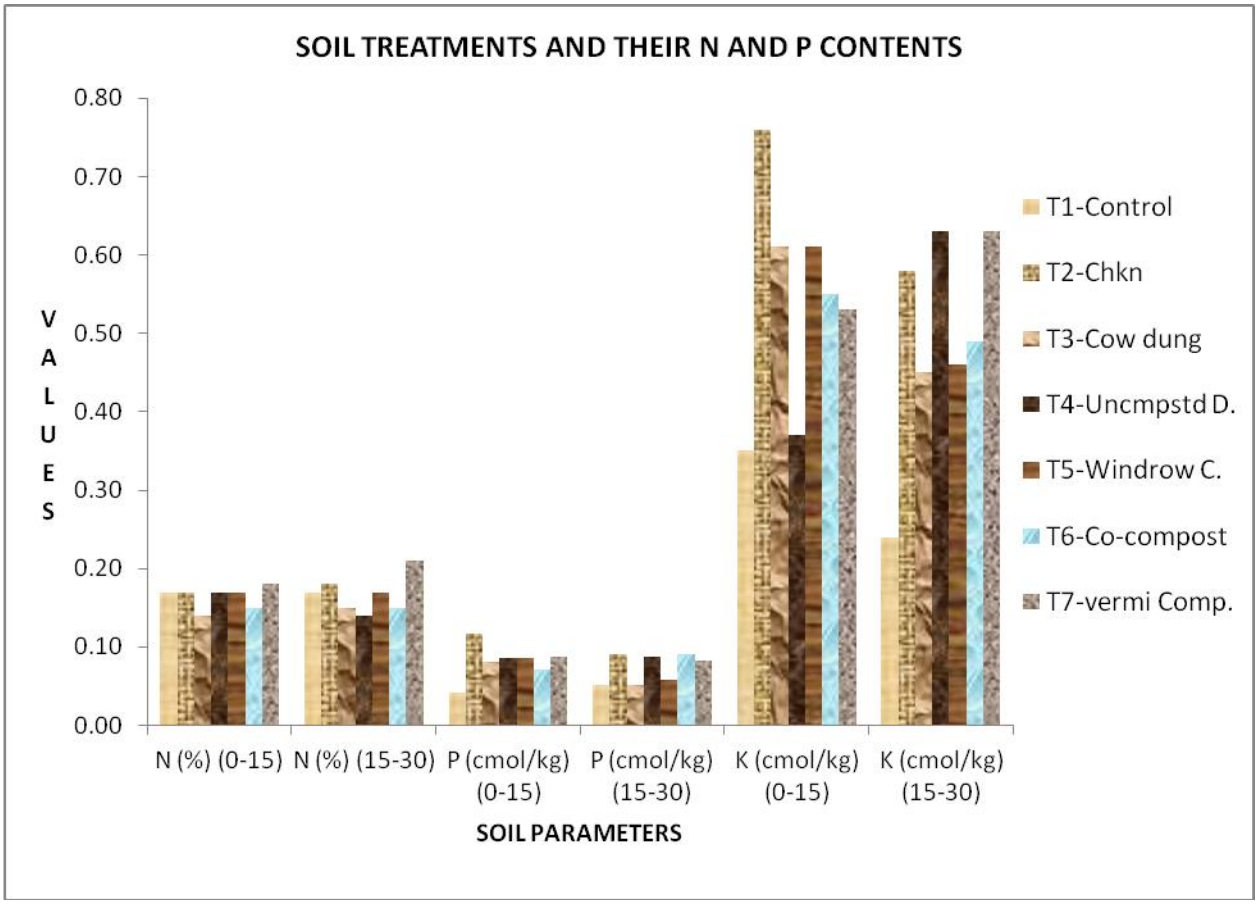

Figure 5: Final Soil Test on N, P and K

The treatments had an effect on the P content. For the top 15 cm, the uncomposted digestate and the windrow compost treatments had the same P content 0.086 cmol/kg and their P content was not different from that of cow dung (0.081 cmol/kg), co-compost (0.072 cmol/kg) and vermicompost (0.088 cmol/kg) treatments. The co-compost and the vermi compost treatments however were different from each other. The chicken manure treatment gave the highest p content (0.116 cmol/kg) and the control treatment being the least (0.042 ccmol/kg). For the 15-30 cm depth of the soil, the control and cow dung treatments produced the least and same P contents (0.051 cmol/kg) whiles the chicken and co-compost treatments produced the highest and same P content (0.091 cmol/kg). The chicken manure treated soils producing the highest P content could be attributed to the high P content in chicken manure which might have caused increased microbial decomposition and release of organic forms of P as reported byMaerere et al. (2000), Bomke and

Lavkulich (1975) and Schegel (1992). Chicken and co-compost treatments producing the same P content could be attributed to similar soil conditions that might have occurred in both treatments at this depth.The uncomposted digestate treatment had the same effect on P content or was not different from the chicken manure, co-compost and the vermi compost treatments but the chicken manure and co-compost treatments were different or had different effect (higher) on P content compared to the vermi compost treatment.

Table 4: Final Soil Test Results and Analysis on K, O.M and O.C

SAMPLE	K (cmol/kg) (0-15)	K (cmol/kg) (15-30)	O.M (%) (0-15)	O.M (%) (15-30)	O.C (%) (0-15)	O.C (%) (15-30)
T1-Control	0.35 a	0.24 a	5.47 a	5.87 a	3.17 a	3.40 a
T2-Chkn	0.76 b	0.58 b	6.80 b	9.80 b	3.94 b	5.71 b
T3-Cow dung	0.61 c	0.45 c	5.57 c	7.59 c	3.23 c	4.40 c
T4-Uncmpstd D.	0.37 d	0.63 d	4.50 d	7.50 c	2.61 d	4.35 d
T5-Windrow C.	0.61 c	0.46 c	6.55 e	7.05 d	3.80 e	4.09 e
T6-Co-compost	0.55 e	0.49 e	6.24 f	6.65 e	3.62 f	3.85 f
T7-vermi Comp.	0.53 e	0.63 d	6.34 g	6.66 e	3.68 g	3.86 f
CV	5.07	3.84	0.55	0.32	0.55	0.32
LSD	0.05	0.03	0.06	0.04	0.03	0.02
F RATIO (TREATMENT)	85.15*	151.93*	1815.19*	8302.39*	1800.84*	8485.89*
F RATIO (BLOCKS)	1.75ns	0.17ns	2.74ns	0.95ns	2.74ns	0.95ns

* - Significant at 5% ns – Not Significant

The treatments had effect on the K content and for the top 15 cm of the soil, the cow dung and windrow compost treatments produced the same K content (0.61 cmol/kg) whiles all the others gave different K contents.The co-compost and vermi compost treatments were not different from each other in terms of K content. Chicken manure treatment produced the highest K content (0.76 cmol/kg) whiles the control treatment produced the least (0.35 cmol/kg). For the 15-30 cm portion of the soil, the uncomposted digestate and the vermi compost treatements produced the same and highest K content (0.63 cmol/kg) followed by the chicken manure treatment (0.58 cmol/kg) and the control treatment (0.24 cmol/kg) produced the least.Treatments which produced the same K content could be attributed to similar soil conditions that might have occurred in both treatments at this depth. The chicken manure treated soils producing high K content could be attributed to the high K content in chicken manure which might have caused increased microbial decomposition and release of K.The high P content from the vermi compost and the uncomposted digestate treated soils could be attributed to high microbial activities from these manuresespecially the vermi compost which involved the use of earthworms.

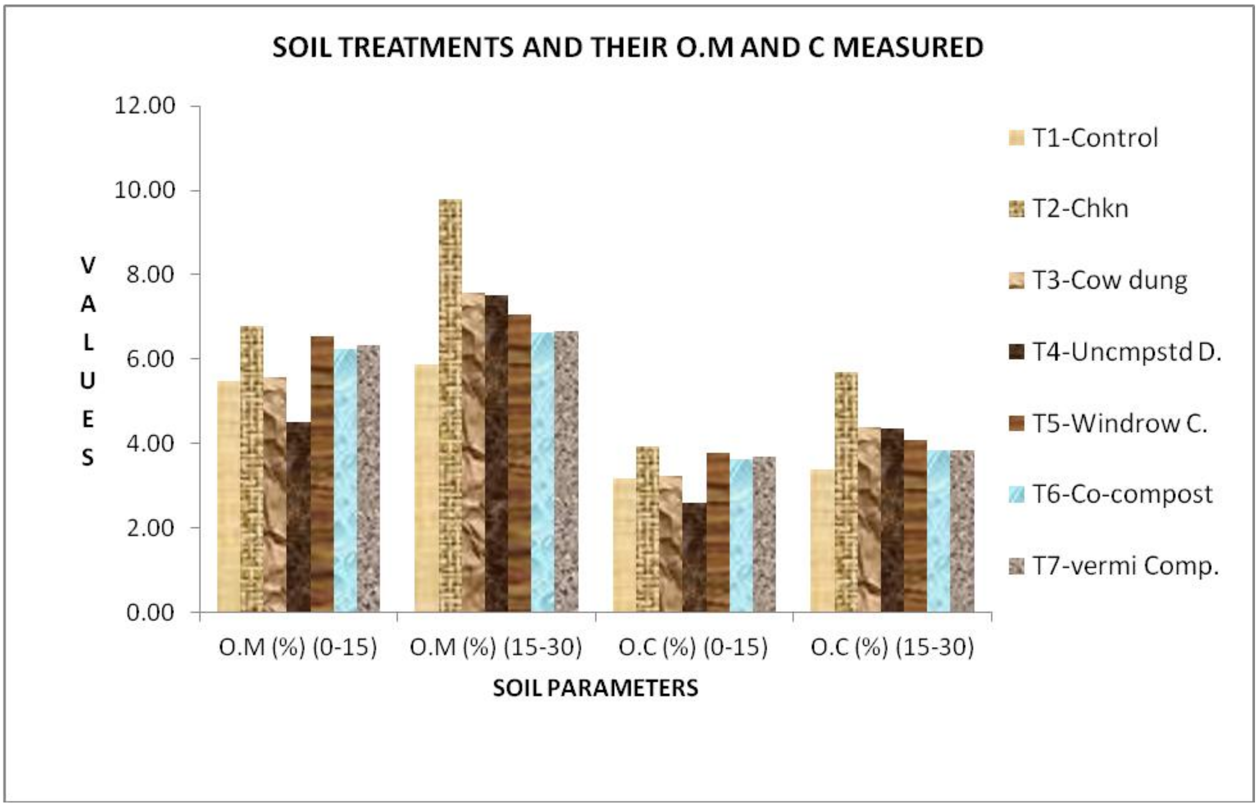

Figure 6: Final Soil Test on O.M and O.C

The treatments had effect on the organic matter content in both depths of the soil samples. For top 15 cm, the different treatments had different effects on the organic matter content. The chicken manure produced the highest organic matter content of 6.80 % followed by the windrow compost treamtment with 6.55 %and then vermi composts and co-compost treatments producing 6.34 % and 6.24 % respectively while the uncomposted digestate treatment produced the least organic matter content of 4.50 %. For the 15-30 cm depth of the soil, the chicken manure treatmtent produced the highest organic matter content of 9.80 % followed by the cow dung treatment (7.59 %) and the uncomposted digestate treatment (7.50 %) which were not different from each other. The vermi compost and the co-compost treatments were also not different from each other and produced 6.65 % and 6.66 % respectively and the control treatment produced the least with 5.87 %. The C content produced for both depths followed the same trend as the organic matter as they were determined by the combustion method which derives carbon from the organic matter content by multiplying the organic matter value by a factor of 0.58. The cow dung and the uncomposted digestate treatments for the 15-30 cm depth however were different from each other as opposed to their organic matter content and this is as a result of approximations in calculations.

Table 5: Final Soil on Al, H and CEC Contents

SAMPLE	Al (cmol/kg) (0-15)	Al (cmol/kg) (15-30)	H (cmol/kg) (0-15)	H (cmol/kg) (15-30)	CEC (cmol/kg) (0-15)	CEC (cmol/kg) (15-30)
T1-Control	0.20	0.20	6.60	6.00	7.66	7.54
T2-Chkn	0.40	0.40	6.60	6.00	7.51	8.30
T3-Cow dung	0.40	0.40	6.20	5.80	8.60	7.79
T4-Uncmpstd D.	0.40	0.40	5.80	6.60	6.92	8.38
T5-Windrow C.	0.20	0.20	6.80	6.80	11.31	10.58
T6-Co-compost	0.60	0.80	6.60	6.80	7.87	9.50
T7-vermi Comp.	0.20	0.60	6.20	6.60	9.34	13.74

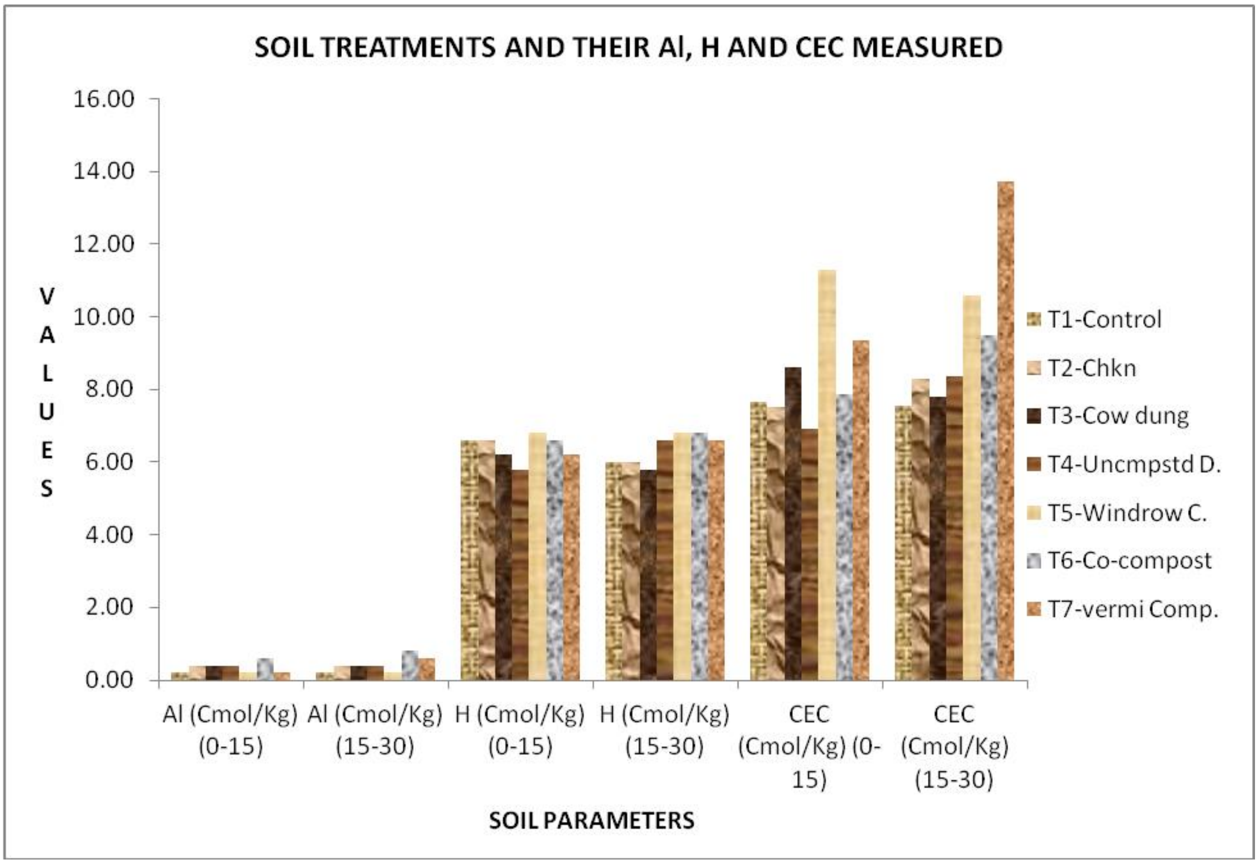

Figure 7: Final Soil Al, H and CEC Contents

K, Ca, Mg and Na values were used for the calculation of the cation exchange capacity (CEC). For the top 15 cm, windrow compost treatment produced the highest CEC (11.31 cmol/kg) followed by vermi compost treatment (9.34 cmol/kg) and chicken manure treatment produced the least CEC (7.51 cmol/kg). For the 15-30 cm portion, the vermi compost treatment produced the highest CEC (13.74 cmol/kg) followed by the windrow compost treatment (10.58 cmol/kg) and the control treatment produced the least CEC (7.54 cmol/kg).

Al and H ion concentrations represent the exchangeable acidity which affects the H ions in the soil solution thereby affecting the soil pH. Al contents in the soil increased from the application of most treatments except windrow treatments in both depths of the soil and vermi compost treatments in the top 15 cm portion. H ion content in the soil increased in all treatments including the control and this means some natural processes in the soil might have also contributed to the increased adsorption of H ions onto the exchangeable sites.

The final particle size distributionsof the samplesfrom the various treatments did not change the soil type from sandy loam.

4. Conclusions

From the study carried out it could be concluded that:

1. Vermi compost of dry fermented digestate increased soil pH and therefore made the soil more basic than the chicken manure, cow dung, the uncomposted dry fermented digestate and its windrow and co-composts. On the other hand, chicken manure‘s pH reduced for the top 15 cm making it more acidic whiles cow dung, uncomposted digestate and co-compost treatment reduced the pH of the 15-30 cm portion of the soil than the other organic manures used.
2. Vermi compost increased soil N more than chicken, cow dung, fresh digestate and its windrow and co-compost as was clearly seen in the 15-30 cm soil depth and relatively in the top 15 cm of the soil. Chicken manure, uncomposted digestate and windrow compost were the next alternatives to vermi compost for N improvement.
3. Chicken manure showed the best improvement of soil P contents compared to the other organic manures. The next best manures for P improvement in the soil were vermi compost and co-compost.
4. For soil K, chicken manure produced the highest in the top 15cm followed by cow dung and windrow composts. For the 15-30 cm portion of the soil, vermi compost and the uncomposted digestate produced the highest K improvement in the soil.
5. For CEC improvement, windrow compost produced the highest for the top 15 cm of the soil followed by vermi compost and for the 15-30 cm portion vermi compost was the best followed by windrow compost.
6. Chicken manure improved soil organic matter best compared with all the other types of organic manures. The next best manures for the top 15 cm was windrow compost and those for the 15-30 cm portions were cow dung manure and uncomposted digestate.

Acknowledgement

The authors are very thankful for the funds provided by Sandec (Department of Water & Sanitation in Developing Countries) at Eawag (Swiss Federal Institute of Aquatic Science & Technology)for the study that generated the data for this paper.

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