RESEARCH PAPER

Compost quality assessment for the household solid wastes of Erbil city

Sayran.Y. Jalal and Yahya. A. Shekha
Department of Environmental Sciences, College of Science, Salahaddin University-Erbil- Kurdistan Region, Iraq

ABSTRACT:
Fifty households were selected for collecting waste from the houses in different quarters of Erbil city for seven days (from 2-October to 8-October 2015). The average rate of solid waste generation in Erbil City was 0.632 kg/capita/day, 732.18 tons/day for all inhabitants of Erbil city. A degradable portion of refuse estimated by 0.377 kg/capita/day which represent 60% of the solid waste composition. Four different procedures were applied to degradation organic waste for compost production: Aerobic, anaerobic, pit and vermicomposting. For compost quality assessment some indices were used as compost quality index (CQI), fertilizing index (FI) and clean index (CI). The value of compost quality index was ranged from (54.73 to 321.12). The compost quality status for all composts types falls under the extremely good category. Fertilizing index value ranged from (3.3 to 4.06 %), while the clean index value for studied composts was 5%. Based on FI and CI values aerobic and anaerobic composts falls under the best quality category, but pit and worm composts fall within the very good quality category. The physicochemical analysis includes: pH, EC, TOC, TP, TN, NO₃, CEC, Ash content, and K⁺ was measured during the study.

KEY WORDS: Household solid waste, Compost production, Compost quality indices.
DOI: http://dx.doi.org/10.21271/ZJPAS.31.6.16
ZJPAS (2019) , 31(6):143-149

INTRODUCTION:
Solid Waste Management (SWM) is the most important and essential problem facing humankind today. The large and growing quantities of solid waste (SW) have become a threat to people and the environment due to the increase in population and urbanization, as well as the toxic components of this waste, and industrial development has become a threat to human beings and the environment (Soufan, 2012). Composting is an aerobic exothermic process for use as a soil conditioner and fertilizer due to the succession of various microbial communities used in biodegradable waste treatment (Shyamala and Belagali, 2015).

Compost prepared from different organic wastes differing in quality and stability, which also depends on the raw material composition used to produce compost.

Successful composting generally depends on some factors that influence the activities of the microorganism directly and indirectly. These including the type of composted raw material, the composition of nutrients, humidity, temperature, alkalinity and aeration (Shyamala and Belagali, 2012).

To classify the various types of compost, four specific quality parameters (which were the combination of one or more properties that regulate the nutrient mineralization from compost, as well as, its post soil application effectivity), were taken up to formulate (CQI) the Compost Quality Index. CQI has been formulated (using four specific parameters of compost quality: total nutrient content, C / N ratio, microbial potential and percent germination) to classify the quality of different compost types as good, moderate, poor, etc. for easy user understanding. By CQI, it could judge the compost quality that is best used (Bera et al., 2013).

The objective of this investigation was to convert household solid waste into compost and reuse it as the soil fertilizer using four procedures.
for compost production: aerobic, anaerobic, pit and vermicomposting, in order to know which method is more convenient.

2. MATERIALS AND METHODS

2.1. Study area:

Erbil is the largest city in Iraqi Kurdistan region and the state capital. The area of Erbil governorate is about 15075 km$^2$, with a population of 1542421, while Erbil city population of 885586 inhabitants (as at 2007), (Erbil Statistic Directorate, 2009). Then the Erbil city population well estimated as 1158520 inhabitants for 2015. According to data obtained from Erbil directorate municipality service and environment, the MSW collected from Erbil city and transported to Kani Kerzhala landfill reached to 2000 tons/day for 2015, while it was more than 2500 tons/day for 2014 and return this reduction in MSW generation to the economic crisis.

2.2. Sample collection and analysis

This study was conducted during the autumn months of the year 2015. Fifty urban houses were selected randomly from different quarters of Erbil city. To reliable estimation quantity of domestic solid waste and generation rate, each family supplied by nylon bags and requested to separated their waste to degradable waste (food scraps, papers of the yard trimmings) and non-degradable waste (plastic, nylon, cans, glass, metals, etc.). Daily samples collected for seven days of consequences from each house (350 samples), brought back to the college of science. The process of waste weighing for each nylon bags was done in glass houses of college, and degradable waste (non-cooked, free fat waste) were separated for composting.

2.3. Generation rate:

The generation rate (capita/day) of domestic solid waste was estimated waste based on the weight-volume analysis; the following equation was used (Aziz et al., 2011).

\[
GR = \frac{\text{Weight of solid waste (g)}}{\text{Population x Duration (d)}}
\]

2.4. Production of Compost types:

Aerobic composting is composting that depends on bacteria thriving in an environment rich with oxygen. Erbil household organic waste, newspaper and triticale straw were used for aerobic composting. The experiment was conducted in a glass house of science college. The aerobic composting was conducted in aerobic condition, the temperature reaches 55°C during composting, and it requires 21 days for maturation (Preda et al., 2013).

Anaerobic digestion involves the breakdown of organic matter in biomass such as animal dung, human excreta, green plant materials, household organic waste, food and so on by microorganisms in the absence of biogas oxygen, a mixture of methane and carbon dioxide with hydrogen sulphide traces. The process needs about two months for maturation and releasing ammonia (Rajeshwari and Balakrishnan, 2000).

While vermicompost is a process by which food materials, cooking waste, including vegetables and fruit peelings, and so on, can be transformed into compost by earthworms. In this study, *Eisenia fetida* as a species of the earthworm to produce compost was used which adapted to decaying organic material (Misra and Roy, 2002).

The last procedure is pit composting, which is recommended when the compost is prepared with soil and refuse. The method is appropriate for areas with low rainfall. Organic residues and light soil are placed in alternating layers, and a 15 - 20 cm thick layer of refuse covers the pit after filling. The materials can remain in the pit for three months without turning and watering. This process required about six months to reach maturation phase. (Misra and Roy, 2002).

After forming or preparing the different types of composts three samples were taken from each type of compost for physicochemical analysis.

2.5. Compost Indices:

The studied indices included: Compost quality index, fertilizing index, and clean index. The compost quality index (CQI) is a numerical expression used to transform large numbers of variables into a single number representing the compost quality level (Table 1), that had been classified according to Bera et al., (2013) which is represented by the following equation:
CQI = \frac{NVNPK \cdot MP \cdot GI}{C\text{ ratio}}

Where:
NVNPK = Total nutrient value in terms of total (N+P\text{2}O\text{5}+ K\text{2}O) percent.
MP = log10 value of total microbial population in terms of total bacteria, total fungi and total actinomycetes.
GI = Germination Index percent.

Table (1). Compost Quality classification according to compost quality index as described by Bera et al., (2013).

| Classification of compost as per compost quality index | Compost Quality Classification |
|--------------------------------------------------------|--------------------------------|
| <2                                                     | Poor                           |
| 2.4-6                                                  | Moderate                       |
| 4-6                                                    | Good                           |
| 6-8                                                    | Very Good                      |
| >10                                                    | Extremely Good                 |

Compost extract was prepared by add 10g of compost in 100ml distilled water. Extract doses of 30, 60, 100% were used, considering distilled water as a control. For germination index three different types of seeds (tomato, wheat and chickpeas), the percentage of germination and root elongation were measured for calculating germination index according to (Bera et al., 2013):

\[
\text{Seed germination}\% = \frac{\text{No. of seeds germinated in compost extract}}{\text{No. of seeds germinated in control}} \times 100,
\]

\[
\text{Root elongation}\% = \frac{\text{Mean of root length in compost extract}}{\text{Mean of root length in control}} \times 100,
\]

\[
\text{Relative Germination index}\% = \frac{\text{Seed germination}\% - \text{Root elongation}\%}{10000}
\]

The fertilizer index was calculated from the contents of the TOC, TN, TP, TK and C: N ratios as described Saha et al., (2010). The MSW compost fertilization index is calculated using the formula:

\[
\text{Fertilizing index (FI)} = \sum \frac{S_i W_i}{W_i}
\]

where 'Si' is a score value of analytical data, and 'W' is weighing factor of the ‘i’th fertility parameter (Table 2).

Table (2). Criteria for ‘weighing factor’ to fertility parameters and ‘score value’ to compost (Saha et al., 2010).

| Fertility Parameters | Score Value (Si) | Weighting Factor (Wi) |
|----------------------|------------------|-----------------------|
| TOC (% dm)           | >20.0            | 4                     |
| TN (% dm)            | >1.25            | 3                     |
| TP (% dm)            | >0.60            | 2                     |
| TK (% dm)            | >1.00            | 1                     |
| C:N ratio            | <10.10           | 1                     |

Note: dm= dry matter.

For clean index calculation, heavy metal concentrations (Zn, Cu, Cd, Pb, Ni, Cr) was used according to (Mandal et al., 2014). Clean index value was calculated by the following formula:

\[
\text{Clean index (CI)} = \sum \frac{S_i W_i}{W_i}
\]

where 'Si' is the score value of analytical data, and ‘Wj’ is weighing factor of the ‘j’th heavy metal (Table 3).

Table (3). Criteria for assigning ‘weighing factor’ to heavy metal parameters and ‘score value’ to analytical data (Saha et al., 2010)

| Heavy metal | Score Value (Si) | Weighting Factor (Wi) |
|-------------|------------------|-----------------------|
| Zn (mg/kg dm) | <151.30       | 1                     |
| Cu (mg/kg dm) | <51.100        | 2                     |
| Cd (mg/kg dm) | <0.3-0.6      | 5                     |
| Pb (mg/kg dm) | <21.100-145.250 | 3                     |
| Ni (mg/kg dm) | <10.10         | 1                     |
| Cr (mg/kg dm) | <51.100-145.250 | 3                     |

2.6. Physico-chemical analysis:

The pH and electrical conductivity (EC) of composts extract measured by using pH-EC meter; while Nitrate content by using the colorimetric method using UV-spectrophotometer as described by APHA (1998). Organic carbon content by using potassium dichromate procedure (Richard, 1954): Cation exchange capacity was measured by using sodium acetate and ammonium acetate exchangeable method (Richard, 1954). Ash content by ignition method at 550°C according to (Allen, 1974), total nitrogen
determined by Kjeldahl method (Van Reeuwijk, 2002); total phosphorus by using the Olsen method (Allen, 1974); and potassium from composts extract by using flame photometer. Heavy metals were measured by using ICP (Inductive complex plasma) as described by (Punsu and Gantheyrou, 2006); while for biological analysis: pour plate count for heterotrophic bacterial count using nutrient agar as a medium as described by Atlas et al., (1995). Total fungi by spread plate count using potato dextrose agar as described by (Aneja, 2012), and spread plate count for total actinomycetes as mentioned by Atlas et al., (1995).

3. RESULTS AND DISCUSSION

The result of household solid waste collection in Erbil city during this study showed an increase in generation rate of solid waste which was estimated by 0.632 kg/capita/day; 732.184 tons.day\(^{-1}\) for Erbil city inhabitants. Biodegradable organic matter represent 60\% (0.377 kg/capita/day) from total SW generation (Figure 1). Erbil city rising SW generation is attributed to an increasing population, the unstable political situation in the country caused emigration from other Iraqi cities to Erbil city. This result is similar to that recorded by Aziz et al., (2011) and Wali (2014), but it is higher than noticed by Shekha (2011). According to data obtained from Erbil directorate municipality service and environment, the MSW collected from Erbil city and transported to Kani Qrzhala landfill reached to 2000 tons/day for 2015, while it was more than 2500 tons/day for 2014 and return this reduction in MSW generation to the economic crisis.

3.1. Compost quality indices:

Compost quality index consists of three important parameters such as nutrient value, total microbial population, C/N ratio and germination index of compost. During the present study, the compost quality index ranged from 1.03 to 25.28 of the studied composts (Table 4). The minimum value recorded for pit compost of chickpeas seeds and maximum value for anaerobic compost of tomato seeds.

Table (4). Compost quality index of the studied composts.

| Seeds  | Doses % | Composting Types |
|--------|---------|------------------|
|        |         | Pit          | Aerobic  | Anaerobic | Worm |
| Tomato | 60      | 2.88         | 3.29     | 25.28     | 11.41 |
|        | 100     | 3.79         | 4.15     | 19.33     | 12.45 |
| Wheat  | 60      | 2.21         | 2.44     | 17.28     | 7.67  |
|        | 100     | 2.12         | 2.39     | 11.47     | 6.5   |
| Chickpeas | 60  | 1.44         | 1.82     | 10.62     | 5.68  |
|         | 100     | 1.63         | 1.55     | 10.94     | 3.97  |

According to Bera et al., (2013) classified tomato and wheat seeds of pit compost as moderate quality, while chickpeas as poor quality. But in aerobic compost classified wheat and chickpeas as poor, while tomato seed as moderate. And in anaerobic compost classified all seeds as extremely good. Therefore, in worm compost classified tomato seed as extremely good, wheat seed as very good, and chickpeas as good quality. The fertilizer index can be taken as a measure of the nutrient supply potential, each analytical data affecting the fertilizer value (responsible for improving soil productivity) of compost. During the present study, the FI ranged from 3.3 to 4.06. The high amount FI in anaerobic compost resulted from a high amount of carbon, nitrogen, potassium and C/N ratio (Mandal et al., 2014). Classification of MSW compost based on marketability and use the different area in accordance to FI value classify the aerobic and anaerobic composts as in class A which means the best quality, but other two types of compost pit and worm composts classify as class B which means very good quality. The present results agree with that found by Saha et al., (2010).

![Figure 1: The degradable and non-degradable wastes in Erbil city in 2015.](image-url)
The regulatory authority can use the Clean Index (CI) value to restrict the entry of heavy metals into sensitive environmental components (such as agricultural land and water bodies) (Mandal et al., 2014). During our study, the CI value in all compost samples was 5, because all composts contain a very small amount of heavy metals (Fig.2). Depend on the MSW classification compost based on marketability and use in the different area in accordance to CI value classify the aerobic and anaerobic compost in class A type which means the best quality but pit and worm composts occur in class B type which means very good quality (Table 4). These results came in accordance with that found by (Saha et al., 2010).

![Figure 2: Clean Index and Fertilizing Index of the studied compost samples.](image)

3.2. Physico-chemical parameters:

As shown in (Table 5) the pH value of different composts was in the alkaline side of neutrality. The minimum value was 7.57 recorded for pit compost, and the different compost types were within the stipulated range (7.2-8.5) for good quality. Change in pH value is due to metabolic activities resulted in the production of CO₂ from organic acids and releases of ammonia. While the electrical conductivity of compost extract was ranged from 244.8μs/cm in vermicompost to more than 1404μs/cm in anaerobic compost. The statistical analysis revealed significant differences (P<0.05) between the composts studied. High EC of composts probably due to the high concentration of soluble salts derived from food and meat waste due to degradation of organic matter (Campell et al., 1997). Total organic carbon varied from 15.76% recorded in anaerobic compost to 24.03% obtained in pit compost. Organic carbon content was found to be reduced in all compost sample degradation. Mondini et al. (2003) noted a decrease in the percentage of organic carbon, which shows the decomposition of the waste by the microbial population.

| Variables | Pit    | Aerobic | Anaerobic | Worm |
|-----------|--------|---------|-----------|------|
| pH        | 7.57   | 8.5     | 8.26      | 7.73 |
| EC (μs/cm⁻¹) | 110,183| 1095    | 1494.66   | 244.83|
| TOC (%)   | 24.03  | 22.93   | 15.67     | 17.91|
| TN (%)    | 0.617  | 0.846   | 2.188     | 0.846|
| TP (%)    | 1.657  | 0.61    | 0.988     | 2.123|
| NO₃/NO₂(N⁺) | 22.2   | 7.94    | 17.59     | 16.43|
| C/N ratio | 39.93  | 37.76   | 37.48     | 31.66|
| C(NaCl)/kg⁻¹ | 58.19  | 33.37   | 37.88     | 9.2  |
| A (%)     | 45.55  | 55.69   | 49.62     | 49.99|
| K (%)     | 0.002  | 0.001   | 0.004     | 0.001|

The total nitrogen content in studied composts varied from 0.617% obtained in pit compost to 2.188% obtained in anaerobic compost. Sanedzie et al., (2012) commented that low availability of nitrogen in pit compost would restrict the microbial activity and stabilization of the waste by composting, and a decrease in nitrogen level could be through volatilization of gaseous ammonium during mixing and processing of the compost heaps. On the other hand, total phosphorous concentration varied in different studied compost, and it was higher than that recommended standard. Maximum value recorded in worm compost (2.123%), In which phosphorus content gradually increased during worm composting process and phosphorus water solubility decreases with humification and immobilization factor (Elango et al., 2009).

Nitrate is a form of inorganic nitrogen and is an important nutrient for plant growth, pit compost characterized by maximum nitrate content (22.2 mg NO₃ N/l) compared with other studied composts, high nitrate content may be attributed to nitrification occurs when all ammonium is mineralized to nitrate after maturation of compost (Bernal et al., 2008). The C: N ratio is one of the most important parameters for the extent of composting and the degree of compost maturity (Dimambro et al., 2007). The C/N ratio of compost sample recorded minimum
value 7.48 in anaerobic compost; this may be due to high moisture percentage. Saha et al., (2010) recommended that too much moisture leads to luck of aeration and leaching. The maximum ratio obtained in pit compost (39.9); this would imply a high proportion of mineralizable carbon while the nature of the organic matter would influence the rate of the process. Shyamala and Belgali (2012) reported that the C/N ratio more than 25 likely indicated stable compost, then worm compost type is regarded as more stable kind.

Cation exchange capacity (CEC) is one of the factors used to describe soil properties and their importance in determining compost maturity and fertility. During composting, CEC is reported to increase (Iqbal et al., 2012). CEC value of 9.209 cmolc/kg recorded in worm compost and maximum value 51.191 cmolc/kg was obtained from pit compost. CEC value in all types of composters, except worm, gradually increased and after became constant. The high CEC pit compost may be related to its organic matter content; particularly the stable organic matter is humus which contributes to cation exchange capacity.

Higher ash content 55.69% for aerobic compost, this may be due to the high amount of potassium. In the composts, high levels of minerals would suggest high ash content. On the other hand, potassium concentration was ranged from 0.36% recorded in pit compost to 0.51% recorded in aerobic compost. Gallardo-lara and Nogales (1987) It has been shown that potassium increases during anaerobic composting and the effective use of certain fibrous materials such as straw or wood chips that can absorb relatively large amounts of water and maintain structural integrity and porosity could prevent the loss of potassium from the compost formed. While, decrease K⁺ in pit compost is due to run-off and leaching of the metal ions with water content present in the solid waste into the ground during the process (Pathak et al., 2012).

CONCLUSION

The study was mainly focusing on performed several procedure for converting household solid wastes into compost, and using it as soil fertilizers. The results revealed that all produced compost types were classified as extremely good quality depending on CQI. The presence of a few amount of heavy metals in the studied compost confirming the good indicators of compost quality.

REFERENCES

ALLEN, S. E. 1974. Chemical analysis of ecological materials, a black well scientific publication. Osney Mead, Oxford.

ANEJA, K. R. 2012. Experiments in microbiology, plant pathology and biotechnology, 4th Ed. New Age International Publishers.

APHA (1998). Standard methods for the examination of water and wastewater, 20th Ed., APHA (American public health association), 1015, 15th. Street, NW, Washington, DC 20005.

ATLAS, R. M.; BROWN, A. E. & PARKS, L. C. 1995. Laboratory manual of experimental microbiology. Mosby-Year Book, Inc. USA.

AZIZ, S. Q.; AZIZ, H. A. BASHIR, M. J. & YUSOFF, M. S. 2011. Appraisal of domestic solid waste generation, components, and the feasibility of recycling in Erbil, Iraq, 29(8): p.880 – 887.

BERA, R.; DAITTA, A.; BOSE, S.; DOLUI, A. K.; CHATTERJEE, A. K.; DEY, G. C.; BARIK, A. K.; SARAK, R. K.; MAJUMDAR, D. & SEAL, A. 2013. Comparative evaluation of compost quality, process convenience and cost under different composting methods to assess their large scale adoptability potential as also complemented by compost quality index, International Journal of Scientific and Research Publications. 3(6): 1–11.

CAMPELL, A. G.; FOLK, R. L. & TRIPEPI, R. R. 1997. Wood ash as an amendment in municipal sludge and yard composting processes. Compost Science and Utilization. 5(1): 62–73.

DIMAMBRO, M. E.; LILLYWHITE, R. & RAHN, C. 2007. The physical, chemical and microbial characteristics of biodegradable municipal waste derived composts. Compost Sci. Utiliz. 15(4): 243–252.

ELANGO, D.; THINAKARAN, N.; PANNEERSELVAM, P. & SIVANESAN, S. 2009. Thermophilic composting of municipal solid waste. Applied Energy, 86(5): 663–668.

Erbil Statistic Directorate. 2009. Erbil governorate population according to food card. (Archive).

GALLARDO-LARA, F. & NOGALES, R. 1987. Effect of application of town refuses compost on the soil-plant system-a review. Biological Wastes. 8(3): 35–62.

Iqbal, M. K.; KHAN, R. A.; NADEEM, A. & HUSSANIAN, A. 2012. Comparative study of different techniques of composting and their stability evaluation in municipal solid waste. The Chemical Society of Pakistan. 34(2): 273–282.

MANDAL, P.; CHATURVEDI, M. K.; BASSIN, J. K.; VAIDYA, A. N. & GUPTA, R. K. 2014. Estimating the quantity of solid waste generation in Oyo. Int J Recycl Org Waste Agricult. 3: 133–139.
MISRA, R. V. & ROY, R. N. 2002. On-farm composting methods. FAO 1980 a manual of rural composting. FAO/UNDP Regional Project RAS/75/004 Field Document 15, pp.1–26.

MONDINI, C.; DELL’ABATE, M. T.; LEITA, L. & BENEDETTI, A. 2003. An integrated chemical, thermal and microbiological approach to compost stability evaluation. Journal of Environmental Quality. 32: 2379–2386.

PATHAK, A. K.; SINGH, M. M.; KUMARA, V.; ARYA, S. & TRIVEDIC, A. K. 2012. Assessment of physico-chemical properties and microbial community during composting of municipal solid waste (viz. kitchen waste) at Jhansi city, u.p. (India). Recent Research in Science and Technology. 4(4):10–14.

PANSU, M. & GAUTHEYROU, J. 2006. Handbook of soil analysis. Springer velage Berlin Heidelberg.

PREDA, G.; LIXANDRU, B. & POPESCU, D. 2013. Practical methods for aerobic composting of cattle manure. Animal science and biotechnologies. Animale Science and Biotechnologies. 46(1): 204–208.

RAJESHWARI, K. V. & BALAKRISHNAN, M. 2000. Aerobic and anaerobic systems for solid waste treatment. Biochemical methods of conversion. pp. 839–851.

RICHARDS, L. A. 1954. Diagnosis and improvement of saline and alkaline soils. United States Salinity Laboratory Staff, USA. Hand Book.

SAHA, J. K.; PANWAR, N. & SINGH, M. V. 2010. An assessment of municipal solid waste compost quality produced in different cities of India in the perspective of developing quality control indices. Waste Management. 30: 192–201.

SANEDZIE, F.; ROCKSON, G. N. & ACHIO, S. 2012. Comparison of compost maturity, microbial survival and health hazards in two composting systems. J. Microbiol. Biotechnol. Food Sci. 2(1): 175–193.

SHEKHA, Y. A. 2011. Household solid waste content in Erbil city, Iraqi Kurdistan Region, Iraq. Zanco J. 23(3): 1–10.

SHYAMALA, D. C. & BELAGALI, S. L. 2012. Studies on variations in physicochemical and biological characteristics at different maturity stages of municipal solid waste compost. International Journal of Environmental Sciences. 2(4): 1984–1997.

SHYAMALA, D. C. & BELAGALI, S. L. 2015. Effect of municipal solid waste and agricultural composts on growth and yield of fenugreek seeds \((Trigonella foenum graecum)\), Research Journal of Pharmaceutical Biological and Chemical Sciences. 6(3): 418–426.

SOUFAN, B. A. 2012. Solid waste management in the west bank: Institutional, legal, financial assessment and framework development, MSc. Thesis. Nablus, Palestine: An-Najah National University.

VANREEUWIJK, L. P. 2002. Procedures for soil analysis. Technical Paper 9. 6th Ed. International Soil Reference and Information Centre. The Netherlands. pp.101.

WALI, K. I. 2011. The domestic solid waste generation management in Erbil city. Zanco Journal of Pure and Applied Sciences. 22(6): 37–52.