# Life cycle assessment approach to analyse the impact of application of urban waste compost for agricultural purpose

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***Abstract*—The disposal of solid waste is one of the major problems faced by fast developing urban areas today. Among all the disposal option of solid waste, Composting can be one of the sustainable solution for waste disposal. Seeing the amount of compost generated through MSW it can be effectively used for agricultural purposes as a replacement for synthetic fertilizer. As synthetic fertilizers do not support microbiological life in the soil and also leads to a negative impact on the environment throughout its lifecycle. Thus, integrated use of synthetic fertilizer along with urban waste compost can be an excellent solution to waste disposal these problems and it would also improve the soil properties. This study focuses on the importance of supplementing synthetic fertilizer with urban waste compost so that it would improve soil properties and analyzing its effect on environment. Life cycle assessment is carried out to predict the impact of integrated use of synthetic fertilizer and urban waste compost on environment.**

***Index Terms*—Synthetic fertilizer, Urban waste compost, Life cycle assessment, Solid waste management**

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## I. INTRODUCTION

The disposal of solid waste has always been a huge problem throughout India. This problem continues to grow with the growth of population and development of industries. Disposal of waste in open pits has become routine in majority of places. The four main methods of disposal of solid waste in India are: a) Landfilling b) Composting c) Incineration d) Recycling. The majority of landfills in India are open dumps without leachate or gas recovery systems. Incineration leads to emission of harmful gases in the environment.

Composting is one of the best methods of waste disposal as it can turn decomposable organic waste into useful compost. The wastes such as remains of plants, garden and kitchen waste undergo bio-degradation process and are turned into nutrient rich food for plants. This can be used in agricultural fields as fertilizer.

Artificial or natural substance containing elements that improve growth and crop productivity are known as fertilizers. Fertilizers enhance the natural fertility of the soil. People are perplexed to which type of fertilizers to use on their agricultural fields [4]. This is because of the different advantages and disadvantages of organic and synthetic fertilizers. Synthetic fertilizers and organic fertilizers have different impacts on crop productivity, soil health and nutrients available to crops.

Organic fertilizers when used releases the necessary nutrients too slow to meet the crop requirements. Si Ho [1] believes that organic compost has a number of shortcomings, like low nutrient content, slow decomposition and different nutrient compositions depending on its organic materials. Thus there is the need of synthetic fertilizer.

However, excessive use of synthetic fertilizer will hamper soil quality and fertility. Research conducted by [2] showed that nitrogen fertilizer application for a long time significantly decreased soil pH, exchangeable Ca, Mg, K as well as Cation Exchange Capacity (CEC). The purpose of this research is to explore the feasibility of supplementing synthetic fertilizer with urban waste compost in view of the fact that it would improve soil quality & to achieve sustainability in waste disposal.

### *A. Disposal options of Municipal solid waste*

The waste disposal has been a matter of concern for several decades, the main problem has been due to growth in population and industrialization, the two major factors that contribute to waste generation. Despite the fact that some advancements has been made in waste disposal methods, they are still not sufficient. The challenge is to develop an optimal method of waste disposal and put the method to use.
The commonly practiced solid waste disposal options in India are: a) Open pits b) Landfills c) Incineration d) Bio-remediation and e) composting. Disposal of solid waste on open pits and landfills leads to generation of leachate. This leads to contamination of both soil and ground water. Further, harmful emissions are also released from these dumping sites. Incineration greatly reduces the volume of waste but it leads to emission of harmful gases in the atmosphere.

This leaves us with the option of composting which is eco friendly, cost effective and an optimum way to tackle the problem of disposal of solid waste.

### *B. Use of MSW compost for agriculture*

Large amount of wastes is produced in towns and cities which eventually causes the problem of disposal of this waste. Composting can be an optimal method for disposal of solid waste as it converts unwanted organic solid waste into useful compost. Compost is a blend that comprises mainly of decayed organic matter and is used for conditioning land and fertilizing. Beneficial microorganisms are induced by compost and organic material. Microorganisms usually found in compost and soil convert organic nitrogen to inorganic nitrogen, this process is called mineralization. The nutrients released by these may then be taken up by plant.

Composts contain an astounding range of microbes, many of which may be advantageous in scheming pathogens. Composting is an economical and effective way to treat animal manure for land application. This is because pathogens and weed seeds are destroyed and the heterogeneous solid-state organic matter is transformed to more stable humic substance by the activity of bacteria [8].

### *C. Feasibility study of supplementing synthetic fertilizer with urban waste compost*

Synthetic fertilizers are essential for nourishing plants and microbes but may have harmful effects on the soil, especially when they are very concentrated and water-soluble. Chemical fertilizer may help soil life, and soil life helps fertilizers and their availability for plants and microbes [3].

Integrated use of synthetic and organic fertilizers would lead to development of sustainable crop production. This may improve the efficiency of synthetic fertilizers and thus reduce their use. Integrated use of organic and synthetic fertilizers is able to improve crop productivity and sustain soil quality and fertility [5]. Study by [6] showed that integrated use of organic wastes and synthetic fertilizers also improve crop yield, soil pH, organic carbon and available N, P and K in sandy loam soil. Other research resulted that application of compost along with synthetic fertilizers produced highest yield and maximum return. [7] Mentioned that organic manure application with chemical fertilizer could maintain soil nutrient balance, enhance nutrient availability, improve soil chemical and physical properties, increase soil organic matter, reducing fertilizer loss rate and improve soil fertility and ecosystem productivity.

### *D. Life cycle assessment for partial replacement of synthetic fertilizer with MSW compost*

Life cycle assessment (LCA) is a tool to quantify environmental burdens associated with products or activities throughout their life cycle, or “from cradle to grave” (Finnveden, 1999; Denison 1996 and Kasai, 1999). LCA as a tool was applied to industrial products initially and developed rapidly during the 1990s. LCA studied the overall environmental burdens generated by products, processes or activities during their entire life cycle, which include extraction and processing of raw materials, manufacturing, production and maintenance, packaging, transportation and distribution and recycling (ISO, 1997). LCA has been used widely to evaluate solid waste management systems as well as for assessment of different scenarios for integrated waste management systems (Moberg et al, 2005; Mendes et al, 2004). The methodological framework used in this paper is the LCA as defined by ISO standards (International Standard Organization, ISO 14040:14043). The general categories of environmental impacts considered include resource use, human health and ecological groups. There are four phases for LCA, which include:
1. Goal definition and scoping
2. Inventory analysis
3. Assessment of potential environmental impacts
4. Interpretation or improvement analysis.

An inventory of energy requirements and selected environmental emissions is performed by analysing the materials and energy flow in and out of the systems. Though the focus is mainly on environmental consequences and energy use, other impact categories such as acidification, eutrophication, photochemical ozone creation potential (POCP), human and eco toxic impacts and operation and maintenance costs are also considered. The negative environmental consequences from the landfill can be more significantly studied and analysed using the LCA tool.
The environmental impacts are assessed in terms of the pollution to ground and water, gas emission to the atmosphere (mainly $CH_4$ and $NO_2$) and the impact on the human population.

## II. MATERIALS AND METHODS

### *A. Experimentation and Treatment*

The experiment was conducted on an agricultural field in Pune city, India. Composite soil sample was collected from 4 locations from the experimental site. The soil samples were mixed and by coning and quartering method the required sample amount was sorted out.

This soil sample was tested for parameters like pH, nitrogen, phosphorus and potassium which are the major nutrients required by agricultural crops. Table 1 shows the result obtained from testing of the soil sample collected.

Table 1: Selected Site Characteristics.

| Parameter | Unit | Value |
|---|---|---|
| Nitrogen (N) | Kg/ha | 213.94 |
| Phosphorus (P) | Kg/ha | 32.67 |
| Potassium (K) | Kg/ha | 365.10 |
| pH | - | 6.40 |

The experimental setup was designed with 5 treatment methods. In each treatment a fixed percentage of synthetic fertilizer was replaced by organic waste compost. The experimental treatments are shown in "Table 2".

Table 2: Treatments in the Experimental Site

| Treatment | Rate |
|---|---|
| 1 | Only synthetic fertilizer |
| 2 | 10% Replacement |
| 3 | 20% Replacement |
| 4 | 30% Replacement |
| 5 | 50% Replacement |

### *B. Nutrient requirement*

The procedure for crop specific fertilizer prediction was adopted following the target yield equation by AICRP on STCR. The crop type chosen is wheat. The target yield equation for wheat is given as:

$$FN = (NR/CF)*100*T – (CS/CF)*SN$$

Where,
FN - Fertilizer nutrient to be applied (kg/ha)
T - Target yield (q/ha)
SN – Soil available nutrient (kg/ha)
NR – Nutrient required (kg/ha of grain production)
CF – Contribution of nutrient from fertilizer (%)
CS - Contribution of nutrient from soil (%)

So, the final equation turned out to be as given below:

$$FN = 7.45T - 0.74\ SN$$
$$FP_2O_5 = 1.90T – 2.88SP$$
$$FK_2O = 2.49T – 0.22SK$$

Using these target yield equations, the additional amount of nutrient required in soil was calculated for a target yield of 50q/ha. The additional nutrients required for the growth of crop are shown in table 3.

Table 3: Additional Nutrient Requirement

| Parameters | Soil nutrients Available | Additional Nutrient required | Synthetic fertilizer required |
|---|---|---|---|
| Nitrogen | 213.94 | 218.68 | 474.5 |
| Phosphorus | 32.67 | 25 | 156.25 |
| Potassium | 365.10 | 44.18 | 76 |

*All values in units kg/ha

### *C. Municipal solid waste compost & its characteristics*

The compost was obtained from "Bhumi green energy (unit 1) plant at Hadapsar, Pune. Organic Municipal solid waste of the city is converted into useful compost. Daily 200-250 tons of waste is treated here. The method of composting used by the plant is windrow composting. Compost was collected from this plant to be used as a partial replacement to synthetic fertilizer. Compost sample was collected and tested for various parameters. The compost parameters are mentioned in table 4.

Table 4: Compost Parameters

| Sr. No. | Parameters | Composition (%) |
|---|---|---|
| 1 | Moisture | 38.16 |
| 2 | Total Nitrogen | 0.31 |
| 3 | Total Phosphate | 0.91 |
| 4 | Water soluble potash | 3.07 |
| 5 | Zinc | 3.989 |
| 6 | Lead | 1.296 |
| 7 | Copper | 19.7 |
| 8 | pH | 6.08 |
| 9 | Cadmium | 1.109 |
| 10 | Odour | Present |
| 11 | Bulk Density | 1.34 |
| 12 | Total Organic Carbon | 13.51 |
| 13 | C:N ratio | 43.3 |
| 14 | Conductivity | 1.89 |
| 15 | Color | Dark black |
| 16 | Particle size - 4 mm | 87.73 |

After analyzing the characteristics of the compost it was found feasible to be used for agricultural purposes.

## III. EXPERIMENTATION AND FERTILIZER APPLICATION

Five plots of 5m x 5m each will be made on the experimental site for carrying out 5 treatments each with different percentage of synthetic fertilizer and organic compost. The treatments are mentioned in Table 2 above. The synthetic fertilizers used for this experimentation were Urea, Single super phosphate (SSP), and Muriate of potash (MOP). The compost used in this experimentation is derived from city organic waste, the characteristics of which are mentioned in “table 4”. A schematic diagram of the experimental site can be seen in “figure 1”.

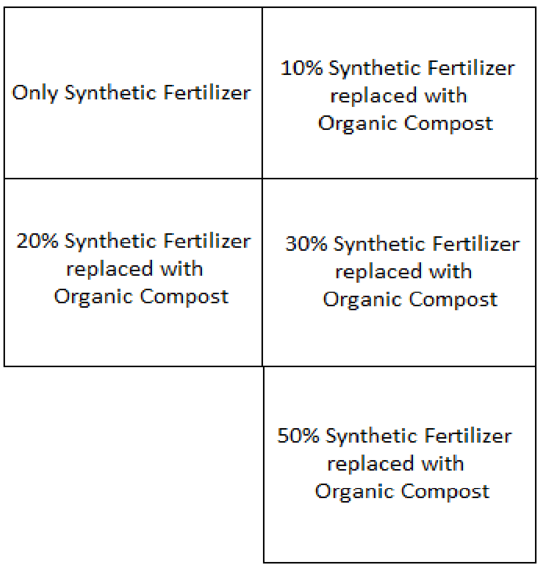


Figure 1: Schematic diagram of the experimental site

### *A. Data collection and analysis:*

After application of synthetic fertilizer and compost for all 5 treatments the plot will be watered and kept idle for an incubation period of 5 days. Samples will be collected from each plot separately and tested. The testing includes primary soil nutrients i.e. nitrogen, phosphorus and potassium. pH of soil will also be tested.

“Open LCA – Green Delta software” will be used to determine the potential impacts of different scenarios. Life Cycle Modeling will be carried out individually for these 5 treatments to predict their impact on environment. The impact parameters considered are Acidification potential, Eutrophication potential, Global warming potential, Human toxicity potential and Photochemical oxidation.

The Inventory data from "Table 5" is used in LCA model to predict the impact of production of commercial fertilizer on environment.

Table 5: Example of Life Cycle Inventory for Production of 1 Kg Commercial Fertilizers (N, P or K)

| | **Unit** | **N** | **P** | **K** |
|---|---|---|---|---|
| Electricity (German) | KWh | 0.217 | 1.06 | 0.15 |
| $H_2SO_4$ | kg (product) | | 2.25 | |
| $H_3PO_4$ | Kg (product) | | 0.79 | |
| $NH_3$ | kg (product) | 0.67 | | |
| $HNO_3$ | kg (product) | 1.78 | | |
| Potassium | g (resource) | | | 12700 |
| Phosphorus | g (resource) | | 4840 | |
| $CaCO_3$ | g (resource) | 550 | | |
| Crude oil | g (resource) | 153 | 70.6 | 10.5 |
| Gas oil | g (resource) | 0.4 | 34 | 11.3 |
| Natural gas | g (resource) | 680 | 231 | 162 |
| Coal | g (resource) | 72 | 13.2 | 29 |
| $CO_2$ | g (emission to air) | 2351 | 923 | 553 |
| $CH_4$ | g (emission to air) | 0.24 | 0.04 | 0.002 |
| $N_2O$ | g (emission to air) | 15.1 | 0.03 | 0.05 |
| $SO_2$ | g (emission to air) | 4.0 | 12.6 | 0.13 |
| CO | g (emission to air) | 2.1 | 0.9 | 0.3 |
| NOx | g (emission to air) | 12.7 | 2.1 | 0.7 |
| NMVOC | g (emission to air) | 0.11 | 0.23 | 0.08 |
| Particles | g (emission to air) | 0.0012 | 0.1 | 0.03 |
| HCl | g (emission to air) | 0.06 | 0.01 | 0.08 |
| $NH_3$ | g (emission to air) | 6.7 | 0.004 | 0.001 |
| Formaldehyde | g (emission to air) | 0.0036 | 0.02 | 0.006 |
| Benz(a)pyrene | g (emission to air) | 0.00036 | $3.7 \times 10^{-7}$ | $1.13 \times 10^{-7}$ |
| As | g (emission to water) | | 0.01 | |
| Cd | g (emission to water) | | 0.01 | |
| Cr | g (emission to water) | | 0.05 | |
| Cu | g (emission to water) | | 0.05 | |
| Hg | g (emission to water) | | 0.01 | |
| Ni | g (emission to water) | | 0.04 | |
| Pb | g (emission to water) | | 0.04 | |
| Zn | g (emission to water) | | 0.06 | |
| F | g (emission to water) | | 167 | |
| $CO_3^{2-}$ | g (emission to water) | | 4500 | |
| Ca | g (emission to water) | | 3000 | |
| Cd | g (input to soil) | 0.0007 | 0.1267 | 0.00013 |
| Cr | g (input to soil) | 0.0102 | 6.2 | 0.0033 |
| Cu | g (input to soil) | 0.0151 | 0.2 | 0.006 |
| Hg | g (input to soil) | $4 \times 10^{-5}$ | 0.0002 | 0.0001 |
| Ni | g (input to soil) | 0.0121 | 0.1 | 0.004 |
| Pb | g (input to soil) | 0.0039 | 0.03 | 0.002 |
| Zn | g (input to soil) | 0.1084 | 0.9 | 0.05 |

Life cycle impact assessment (LCIA) was also carried out to predict the impact of urban waste on environment.

Table 6: Life Cycle Inventory For 1 Kg Solid Waste Related To Land Filling Scenario.

| **Input** | | **Output** | |
|---|---|---|---|
| Rest waste | 1 kg | Occupied landfill volume | 0.7 m3 |
| Diesel for dumping | 0.026 MJ | Purified landfill Leachate | 0.3 MJ |
| Electric energy | 0.0074 MJ | | |
| | | Air emissions | |
| | | $CH_4$ | 21 |
| | | $CO_2$ | 178 |
| | | CO | 119 |
| | | $NO_X$ | 107 |
| | | Water emissions | |
| | | COD | 64 mg |
| | | BOD | 16 mg |
| | | Phosphorus (P) | 4 mg |
| | | Nitrite | 0.24 mg |
| | | Nitrate | 8 mg |
| | | Sulphate | 400 mg |
| | | Sulphite | 0.2 mg |
| | | Chloride | 480 mg |
| | | Fluoride | 2.4 mg |
| | | Ammonia | 6 mg |
| | | Copper | 0.04 mg |
| | | Iron | 0.8 mg |
| | | Lead | 0.08 mg |
| | | Cadmium | 0.008 mg |
| | | Zinc | 0.2 mg |
| | | Mercury | 0.002 mg |
| | | Manganese | 0.8 mg |
| | | Chromium | 0.8 mg |
| | | Nickel | 0.8 mg |
| | | Tin | 4 mg |
| | | Arsenic | 0.2 mg |

The Inventory data from table 6 will be used in LCA model to predict the impact of municipal solid waste from landfill on environment. This amount of impact on environment can be saved by composting of this waste.

Using these inventory data and amount of synthetic fertilizer and compost used, the impact on environment of these treatments will be predicted.

## IV. RESULT AND DISCUSSION:

The soil nutrient parameters after treatment is shown “Table 7”. The required value of nitrogen i.e. approximately 430 kg/ha is achieved at 20% replacement. Phosphorus and potassium requirements are achieved for all treatments.

After carrying out life cycle assessment for the 5 treatments it was observed that the potential environment impact reduces with reduced use of synthetic fertilizer.

Table 7: Soil Nutrients after Treatment

| **Treatment** | **Nitrogen** | **Phosphorus** | **Potassium** |
|---|---|---|---|
| Only synthetic fertilizer | 436.89 | 58.53 | 410.39 |
| 10% replacement | 434.22 | 63.69 | 408.02 |
| 20% replacement | 429.80 | 68.85 | 412.03 |
| 30% replacement | 427.18 | 71.97 | 418.90 |

| | | | |
|---|---|---|---|
| 50% replacement | 410. 04 | 79.98 | 425.46 |

*All units in kg/ha

Life cycle impact assessment (LCIA) for different treatment considered. Figures below show the environmental impact based on different treatments considered.

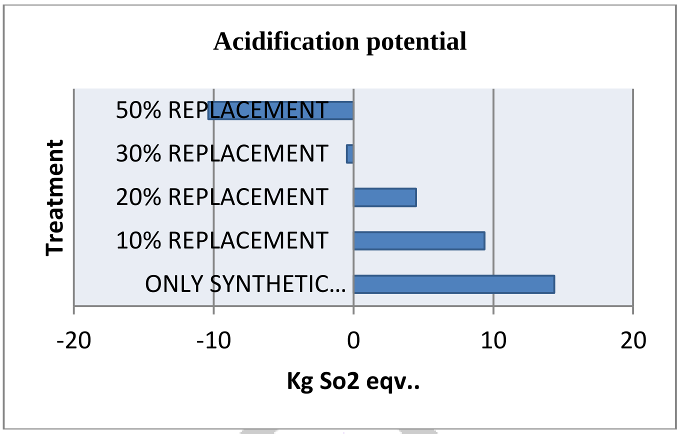


Fig. 2: Acidification potential

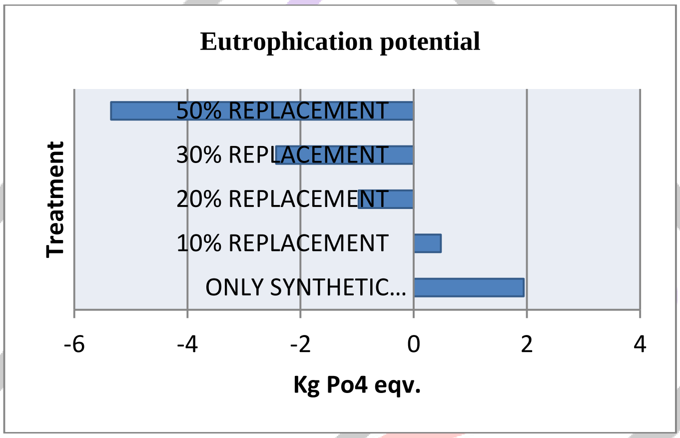


Fig. 3: Eutrophication potential

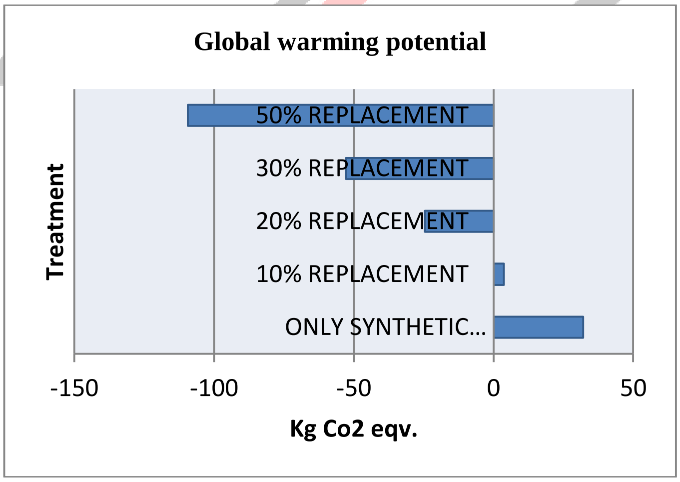


Fig. 4: Global warming potential

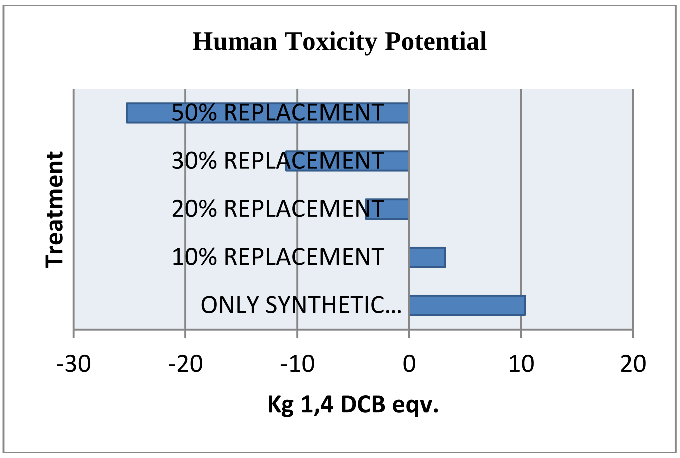


Fig. 5: Human toxicity potential

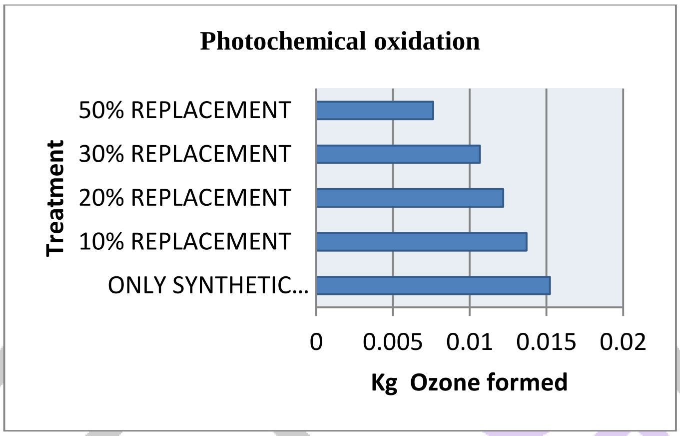


Fig. 6: Photo chemical oxidation

## V. CONCLUSION

It can be concluded from the present study that an integrated use of synthetic and urban waste compost would satisfy the nutrient requirement and help to maintain soil health. . The results of these 5 treatments portrays that around 20% of synthetic fertilizer can be replaced with organic compost.

An important benefit in replacing a part of synthetic fertilizer with urban waste compost is the reduction in production of synthetic fertilizer. The production and transportation of synthetic fertilizer on a whole contributes to increase of abiotic depletion, global warming potential, ozone layer depletion potential, photochemical oxidation, acidification and eutrophication. This can be stated by carrying out life cycle assessment of synthetic fertilizer.

On the other hand the use of urban waste compost not only resolves one of today's major problems of disposal of urban waste but also provides nutrition to plants and soil. In addition to this, natural compost induces beneficial microbes in soil which help to control plant pathogens and enhances soil fertility.

## REFERENCES

[1] Si Ho Han, Ji Young An, Jaehong Hwang, Se Bin Kim & Byung Bae Park, (2016), "The effects of organic manure and chemical fertilizer on the growth and nutrient concentrations of yellow poplar (Liriodendron tulipifera Lin.) in a nursery system", Forest Science and Technology, Vol. 12, 137_143.
[2] A.E. Russell, D.A. Laird, and A. P. Mallarino, (2006), "Nitrogen fertilization and cropping system impacts on soil quality in Midwestern Mollisols," Soil Sci. Soc. Am. J. vol 70, no 1 pp 249-255.
[3] Mader P, Fliessbach A, Dubois D, Gunst L, Fried P, (2002), "Soil fertility and biodiversity in organic farming". Science 296: 1694-1697.
[4] Z. Muktamar, S. Sujatmiko, B. Toha, and M. Asteria, (2012), "Farmers are sacrificing their health for production of vegetables," In Proc. International Conference on Sustainable Agriculture and Food Security: Challenges and Opportunities, pp. 141-149.
[5] V. Satyanarayana, P.V.V. Prasad, V.R.K. Murthy and K.J. Boote, "Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice," Ind. J. Plant Nutr.

[6] S.K. Rautaray, B.C. Ghosh and B.N. Mittra, (2003), "Effect of fly ash, organic wastes and chemical fertilizers on yield, nutrient uptake, heavy metal content and residual fertility in a rice-mustard cropping sequence under acid lateritic soils,: Biores. Tech. no 90, pp 275-283.
[7] Conacher J, Conacher A, (1998), "Organic farming and the environment, with particular reference to Australia". Biological Agriculture Horticulture.
[8] Guo R, Schuchardt F, Li G, Jiang T, Chen T, (2012) "Effect of aeration rate, C/N ratio and moisture content on the stability and maturity of compost". Bioresour Technol 8: 112-171.