Phytoassessment of a spent carbide-contaminated soil obtained from an auto mechanic workshop after substrate amendment with digestate obtained from a biogas plant in Benin City

Ikhajigbe B¹, Mshelmbula BP²

1. Environmental Biotechnology and Sustainability Research Group, Department of Plant Biology and Biotechnology, University of Benin, Nigeria
2. Department of Biological Sciences Adamawa State University, Mubi, Nigeria

*Corresponding author email: barkapeter5@gmail.com

Abstract

The study investigated the improvement in soil quality of soil collected from an auto mechanic workshop that had been polluted with spent carbide and spent engine oil waste (SEOW) after amendment with digestate from biofuel production. The remediated soil was later phytoassessed by using germination and growth parameters of Telfaria occidentalis (pumpkin) as yardstick. The physico-chemical properties, heavy metal content and total hydrocarbon content (THC) of the soil were also investigated. The soil was polluted with SEOW of 5% w/w and four different levels of spent calcium carbide treatment of 0%, 2.5%, 5.0%, and 10.0% w/w. One set was amended with digestate (+D) while the other set was unamended (ND). The result obtained showed that soil pH increased from 7.10 at the start of the experiment to 9.35 – 11.2 three months later when soil was subjected to experimental conditions. Also significantly increased were the soil’s electric conductivity from (420 to 680 µS/cm) and potassium content (0.51 – 1.09 meq/100g). There was significant reductions in all the heavy metals sampled 3 months after exposure to the experimental conditions. Higher concentrations of spent carbide in the soils implied lower remediation of heavy metals and total hydrocarbons. Phytoassessment with T. occidentalis shows that generally, the plant in 10% carbide amended-oil polluted soil (digestate amended) did not survive, whereas those ones in the non-amended soil (10 %C, ND) survived. Plant height in 10 %C (ND) was 48.8 cm and a yield of 33 leaves per plant, compared to the control (0 %C, ND) which height and number of leaves were 41.5 cm and 50 leaves respectively. There were no significant differences between plants parameters in polluted soils of similar carbide concentration irrespective of whether or not the soils were eventually substrate amended with digestate.

Key words: Phytoassessment, biofuel digestate, amendment, spent carbide, hydrocarbon, calcium carbide

Introduction

A major part of the natural ecosystem is the soil. Plants, animals, microorganisms and man rely on it for survival (Adriano et al., 1998). Plants require a pleasant environmental condition and nutrient to be provided for them to grow well. Unfortunately, unmanaged, over and ever increasing human population is beginning to occupy rich agriculture lands. Areas around towns and big cities, which were fertile and cultivated a decade ago, has replaced now by housing schemes and factory works, as well as oil-polluted soils particularly as a result of indiscriminate dumping of waste lubricating oil. Some of these oil-polluted soils in most mechanic shops visited in Benin City, Nigeria, also complicate the oil-polluted soil situation by also dumping spent calcium carbide, which the auto mechanics use. A very popular practice by auto mechanics in Benin City is the siting of workshops on open vacant plots either very close to farmlands or, in vry many cases, on unused portions of farmlands. Compared with the past, today we have more mouths to feed and more bodies to dress but no more land for the cultivation of arable crops. This situation forces one to increase per unit area production of major crops like fluted pumpkin, which is about the most popularly sort after vegetable crop in the City. Vegetables are an important part of human’s diet. In addition to a potential source of important nutrients, vegetables constitute important functional food components by contributing protein, vitamins, iron and calcium which have marked health effects. Vegetables, especially those of leafy...
vegetables grown in oil-contaminated soils usually do show good growth and yield performance because a number of factors including direct oil-poisoning, clogged soil, as well as poor soil condition, including poor nitrogen use efficiency. The application of encapsulated calcium carbide (ECC), which releases acetylene (C$_2$H$_2$) in soil for a long time, thereby delaying the nitrification process in the soil (Banerjee and Mosier, 1989; Banerjee et al., 1990) has been one of the ways of improving nitrogen use efficiency by plants.

Calcium carbide as rich source of acetylene prevents the process of nitrification and ethylene which is a plant hormone. It produces acetylene gas when there is a reaction with water. The acetylene gas produced is then reduced to ethylene in the presence of the enzyme nitorgenase with the aid of microorganism. The ethylene formed from the reduction of acetylene by living organisms may concentrate in the soil at functionally active levels. Acetylene also restricts the action of the enzyme that aids the oxidation of ammonia involved in the process of nitrification (Ahmed et al., 2003; Kashif et al., 2007). Notwithstanding, the poisonous effect of spent carbide reduces as time goes by due to the conversion of calcium hydroxide into calcium carbonate. Moreover, such a natural equilibrual process would happen over many years or decades in instances when a large amount of the waste was present (Semikolenykh et al., 2012).

Tanee and Ochekwu (2010) investigated the impact of different levels of spent carbide on the growth and yield of Zea mays Linn. (maize) and Arachis hypogea Linn. (groundnut). The crops were planted in carbide waste in four concentrations. They observed that carbide waste had adverse affects on plant height, fresh weight and dry weight yield of the two crops (maize and groundnut) especially at higher carbide waste concentrations. They reported that Zea mays experienced highest yield in total fresh weight, shoot dry weight and total dry weight at medium concentration of carbide waste while Arachis hypogea showed highest yield in total fresh weight, shoot dry weight, root dry weight and total dry weight at the least concentration of carbide waste. They concluded that both crops can tolerate carbide waste pollutant at low concentrations but the phytoxoticity of this waste was high at higher concentrations.

In combination with the deleterious effects already imposed by the oil in soil (De Jong, 1982), the impact on highly economic crops like Telfaria occidentalis would have devastating impact on the populace. The present study therefore investigates the impact of amendments using digestate obtained from a local biogas plant in Benin City, on the survival and growth performance of Telfaria occidentalis. These problems can sometimes be dealt with in a number of ways towards ensuring the desired result is achieved. One of the ways is by direct use of substrate amendments. Some of these problems can be dealt with by using substrate amendment (Ikhajiagbe, 2010; Ikhajiagbe and Anoliefo, 2010, 2011). Substrate amendment also known as soil amendment is any material that is added to a soil to improve its physical characteristics, such as water holding capacity, ease for passage of solutes, easy flow of water, drainage, free flow of air and structure of the soil (Davis and Wilson, 2005).

The type, combination and concentration of substrate amendments to be used on a site will differ from site to site in relation to the content of soil’s pollutant in that particular area, the state in which the soil is and the type of vegetation desired at the end. The primary and most important part of any substrate amendment strategy is a precise evaluation of the previous conditions of the soil and idea of the type of soil conditions that will be achieved at the end and that is right for the type of plant species of interest to be cultivated on the soil. Also, it is important that soil amendments to be used should be carefully analyzed for all necessary physical, chemical and microbiological components (EPA, 2007).

Different kinds of substrate are available for use to enhance soil health; however, the researchers shall depend solely on digestate as a source. Soil amendments have the potential to protect the environment and also remediation, revitalization and reuse of disturbed sites by reducing contaminant bioavailability at lower cost than other available options. At many sites, this technology may be the only economically viable treatment option. In addition, this approach offers the benefit of recycling municipal and industrial residuals to reclaim damaged or disturbed land rather than disposing of what is generally considered to be waste in landfills or by incineration (EPA, 2007).

**Materials and methods**

The study area for the research was a plot of land beside the botanic garden of the Department of Plant Biology and Biotechnology, Ugbowo campus, University of Benin, Benin City, Nigeria, which lies within the rainforest ecological zone of Midwestern Nigeria. Soil used in the present study was collected from a mechanic workshop in Benin City, Nigeria.

Top soil (0 – 10 cm) was collected from a mechanic workshop in Oluku, Benin City. The soil was then amended with spent carbide at the rates; 2.5, 5.0, and 10.0% w/w. the control soil was unpolluted and unamended. These carbide-amended oil-polluted soils were divided into 2 sets; one set was further uniformly amended with biogas digestate at a constant 10 % w/w concentration. Having previously determined the soil’s water holding capacity to be 211 ml/kg soil, the moisture requirements for the polluted soils were met by wetting weekly with 1000ml distilled water (Ikhajiagbe et al., 2013). This entire setup was left undisturbed for a period of 3 months in a well ventilated screen house.

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Soil Physicochemical Analyses
Soils were dried at ambient temperature (22-25°C), crushed in a porcelain mortar and sieved through a 2-mm (10 meshes) stainless sieve. Air-dried <2 mm samples were stored in polythene bags for subsequent analysis. The <2 mm fraction was used for the determination of selected soil physicochemical properties and the heavy metal fractions (Ikhajiajbe, 2010). Total organic carbon (TOC) and total organic matter (TOM) contents were determined according to (Nelson and Sommers, 1982) and (Osuji and Nwoye, 2007).

Extraction of Micronutrients in Soils by Hydrochloric Acid Method
Ten (10) g of soil was weighed into a 250 ml plastic bottle. 100 ml of 0.1 m HCl was added, stopper, and then shaken for 30 minutes. The mixture was filtered through Whitman filter paper No.42. And then Fe, Cu, Mn, Zn, Cd, Cr, Pb, Ni, and V were determined in the filtrate by Atomic Absorption Spectrometry.

Phytoassessment
The success of remediation at 3 months was assessed by sowing pumpkin (Telfaria occidentalis) in remediated soils. The plants were observed for the following parameters; Plant height, No. of primary branches, No. of leaves per plant, Leaf area (cm²), as well as Chlorophyll content index (CCI). Analysis of variance in completely randomized design was done using the SPSS-15 statistical software, and means were separated by using the Least Significant Difference.

Results
The chemical composition of soil and digestate used in the present study have been presented in Table 1(a,b). The chemical properties of soil after three months of exposure to various treatment showed that the pH ranged from a 7.49 to 11.2, electrical conductivity ranged from 440µS/cm to 680µS/cm (Table 2). Organic carbon increased over 3 months from 0.42% at the start to between 1.20 – 1.58% in the carbide-amended soils. Nitrogen content of soil in the carbide-amended soil was comparable with that at the start of the experiment (0.21%). In the soil that was never amended with carbide, total nitrogen was 0.07 – 0.09 %. No significant differences in concentration of calcium in the soil were recorded; values ranged between 4.17 – 7.64 meq/100g (Table 2).

Table 1. Chemical properties of soil and digestate used for the present study

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>EC (µS/cm)</th>
<th>Org. C (%)</th>
<th>Total (%)</th>
<th>N (%)</th>
<th>K (meq/100g)</th>
<th>Ca</th>
<th>Mg</th>
<th>SO₄ (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>7.10</td>
<td>420</td>
<td>0.42</td>
<td>0.21</td>
<td>0.51</td>
<td>4.93</td>
<td>3.64</td>
<td>52.84</td>
<td></td>
</tr>
<tr>
<td>Digestate</td>
<td>7.66</td>
<td>570</td>
<td>2.06</td>
<td>0.17</td>
<td>1.20</td>
<td>7.08</td>
<td>5.98</td>
<td>85.37</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Chemical properties of soil after 3 months of exposure to various treatments

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>EC (µS/cm)</th>
<th>Org.C (%)</th>
<th>Total N (%)</th>
<th>K (meq/100g)</th>
<th>Ca</th>
<th>Mg</th>
<th>SO₄ (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.42</td>
<td>0.21</td>
<td>0.51</td>
<td>4.93</td>
<td>3.64</td>
<td>52.84</td>
</tr>
<tr>
<td>3 months later</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10% C (D)</td>
<td>10.9</td>
<td>680</td>
<td>1.58</td>
<td>0.13</td>
<td>0.86</td>
<td>7.56</td>
<td>5.10</td>
<td>63.55</td>
</tr>
<tr>
<td>10% C +D</td>
<td>11.2</td>
<td>609</td>
<td>1.20</td>
<td>0.19</td>
<td>1.08</td>
<td>6.99</td>
<td>4.58</td>
<td>53.21</td>
</tr>
<tr>
<td>5% C (ND)</td>
<td>10.0</td>
<td>620</td>
<td>1.29</td>
<td>0.12</td>
<td>0.44</td>
<td>5.25</td>
<td>2.02</td>
<td>52.41</td>
</tr>
<tr>
<td>5% C + D</td>
<td>9.66</td>
<td>450</td>
<td>1.54</td>
<td>0.13</td>
<td>0.91</td>
<td>7.13</td>
<td>5.34</td>
<td>45.73</td>
</tr>
<tr>
<td>2.5% C (ND)</td>
<td>9.83</td>
<td>520</td>
<td>1.34</td>
<td>0.11</td>
<td>1.02</td>
<td>8.05</td>
<td>6.20</td>
<td>55.59</td>
</tr>
<tr>
<td>2.5% C + D</td>
<td>9.35</td>
<td>536</td>
<td>1.39</td>
<td>0.13</td>
<td>1.09</td>
<td>7.64</td>
<td>6.22</td>
<td>53.96</td>
</tr>
<tr>
<td>0% C (ND)</td>
<td>7.88</td>
<td>440</td>
<td>0.54</td>
<td>0.07</td>
<td>0.57</td>
<td>4.17</td>
<td>2.29</td>
<td>54.92</td>
</tr>
<tr>
<td>0% C + D</td>
<td>7.49</td>
<td>460</td>
<td>1.18</td>
<td>0.09</td>
<td>0.96</td>
<td>3.89</td>
<td>5.98</td>
<td>50.41</td>
</tr>
</tbody>
</table>

%C percentage of waste carbide on weight basis that was added to soil; +D digestate added to the soil; ND no digestate was added to soil.

Means on the same column with the same superscript alphabet do not differ from each other significantly (p>0.05)

Table 3 shows Heavy metal components of soil after 3 months of exposure to various treatments. There was significant reductions in all the heavy metals sampled 3 months after exposure to the experimental conditions. The application of spent carbide to soil resulted in reduced remediation of Fe. Fe content in the carbide-amended soils ranged from 98.65 –
320.50 mg/kg, compared to 21.25 – 63.05 mg/kg in the soils without carbide (0% C). At the start of the experiment, Mn was 39.20 mg/kg, but 3 months later it was 13.50 mg/kg in 10%C (ND) and 11.20 mg/kg in 10% C+D. Generally, soils with lower concentrations of spent carbide had lower concentrations of heavy metals compared to those amended with higher concentrations. Similarly, the present of carbide in soil hampered remediation of metal contents in soil, as well as total hydrocarbon content.

Table 3. Heavy metal components of soil after 3 months of exposure to various treatments

<table>
<thead>
<tr>
<th>Soil</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
<th>Cu</th>
<th>Cr</th>
<th>Cd</th>
<th>Pb</th>
<th>Ni</th>
<th>V</th>
<th>THC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshly collected soil</td>
<td>773.20</td>
<td>39.20</td>
<td>53.33</td>
<td>26.32</td>
<td>10.96</td>
<td>13.50</td>
<td>13.10</td>
<td>10.09</td>
<td>8.92</td>
<td>2536.54</td>
</tr>
<tr>
<td>3 months later</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10% C (ND)</td>
<td>320.50</td>
<td>13.50</td>
<td>26.32</td>
<td>10.52</td>
<td>3.21</td>
<td>6.65</td>
<td>5.32</td>
<td>4.52</td>
<td>2.88</td>
<td>621.98</td>
</tr>
<tr>
<td>10% C +D</td>
<td>254.21</td>
<td>11.20</td>
<td>20.52</td>
<td>8.51</td>
<td>1.65</td>
<td>4.62</td>
<td>0.95</td>
<td>0.01</td>
<td>0.01</td>
<td>461.52</td>
</tr>
<tr>
<td>5% C (ND)</td>
<td>204.23</td>
<td>9.65</td>
<td>20.51</td>
<td>8.62</td>
<td>3.21</td>
<td>4.22</td>
<td>3.82</td>
<td>1.67</td>
<td>1.95</td>
<td>360.95</td>
</tr>
<tr>
<td>5% C + D</td>
<td>198.32</td>
<td>7.22</td>
<td>16.38</td>
<td>5.64</td>
<td>1.08</td>
<td>2.51</td>
<td>1.68</td>
<td>1.07</td>
<td>0.34</td>
<td>200.05</td>
</tr>
<tr>
<td>2.5% C (ND)</td>
<td>163.21</td>
<td>5.32</td>
<td>12.58</td>
<td>3.57</td>
<td>1.85</td>
<td>2.11</td>
<td>1.28</td>
<td>1.09</td>
<td>0.63</td>
<td>132.21</td>
</tr>
<tr>
<td>2.5% C + D</td>
<td>98.65</td>
<td>2.55</td>
<td>6.85</td>
<td>1.57</td>
<td>1.04</td>
<td>0.28</td>
<td>1.06</td>
<td>0.08</td>
<td>0.01</td>
<td>79.01</td>
</tr>
</tbody>
</table>

**Means on the same column with the same superscript alphabet do not differ from each other significantly (p>0.05)**

Table 4. Some plant parameters of test plant (T. occidentalis) in remediated carbide amended oil-polluted soil at 40 days after sowing

<table>
<thead>
<tr>
<th>Soil</th>
<th>Plant height (cm)</th>
<th>No. of branches</th>
<th>No. of primary leaves</th>
<th>Leaf area (cm²)</th>
<th>Chlorophyll content index (CCI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% C (ND)</td>
<td>48.8f</td>
<td>24f</td>
<td>33f</td>
<td>28.35f</td>
<td>15.1f</td>
</tr>
<tr>
<td>10% C +D</td>
<td>0f</td>
<td>0f</td>
<td>0f</td>
<td>0f</td>
<td>0f</td>
</tr>
<tr>
<td>5% C (ND)</td>
<td>37.7e</td>
<td>21d</td>
<td>32d</td>
<td>30.47e</td>
<td>19.4e</td>
</tr>
<tr>
<td>5% C + D</td>
<td>44.2f</td>
<td>23f</td>
<td>38f</td>
<td>29.54f</td>
<td>23.3f</td>
</tr>
<tr>
<td>2.5% C (ND)</td>
<td>23.4d</td>
<td>15e</td>
<td>25e</td>
<td>19.21d</td>
<td>14.5d</td>
</tr>
<tr>
<td>2.5% C + D</td>
<td>22.9d</td>
<td>17d</td>
<td>30d</td>
<td>21.53d</td>
<td>20.2d</td>
</tr>
<tr>
<td>0% C (ND)</td>
<td>41.5c</td>
<td>32c</td>
<td>50c</td>
<td>35.64c</td>
<td>24.1c</td>
</tr>
<tr>
<td>0% C +D</td>
<td>38.5e</td>
<td>29d</td>
<td>41d</td>
<td>28.73d</td>
<td>31.3d</td>
</tr>
</tbody>
</table>

**Means on the same column with the same superscript alphabet do not differ from each other significantly (p>0.05)**

**NA = not available; %C percentage of waste carbide on weight basis that was added to soil; +D digestate added to the soil; ND no digestate was added to soil.**

![Figure 1. Presence of leaf chlorosis in T. occidentalis in remediated carbide amended oil-polluted soil. %C = percentage of waste carbide on weight basis that was added to soil; +D digestate added to the soil; ND = no digestate was added to soil.](image)

Plant height in the control soil (0 %C, ND) was 41.5 cm at 40 days after sowing (Table 4, Plate 1), compared to 38.5 cm when control soil was amended with digestate. Generally, the plant in 10% carbide amended-oil polluted soil (digestate amended) did not survive. However, the plant in the soil that was not amended with digestate survived, with 48.8 cm as plant height and a yield of 33 leaves per plant, compared to the control (unamended) which height and number of leaves were 41.5 cm and 50 leaves respectively. There were no significant differences between plant parameters in polluted soils of similar carbide concentration irrespective of whether or not the soils were eventually substrate amended with digestate. There were 50
number of leaves in the unamended control, compared to 17 – 24 leaves per plant) in the treatments. Similarly, leaf area was higher in the control soil, compared to those in the various experimental treatments (19.21 – 30.47 cm$^2$).

The presence of chlorosis (Fig. 1; Plate 1) in the T. occidentalis in remediated carbide-amended oil-polluted soil was visible from the 16th day after sowing. However, there was no chlorotic leaf in plants sown in control soils.

Discussion

The present study thus investigated the enhancement of plant growth sown in a spent carbide-impacted oil-polluted soil after substrate amendment with digestates from a biogas plant. The digestate used for the phytoassessment had a higher carbon content which according to Wilfred et al. (2002) stimulates the biodegradation of hydrocarbon in the soil.

Three months after exposure (3MAE) for the various treatment, there was an increase in pH of the soil, E.C, organic carbon, sodium, potassium, calcium manganese and chloride contents, available phosphorus, ammonium, nitrate and sulphate content of the soil. There was a decrease in total Nitrogen. Abioye et al., 2009a,b and Agamuthu and Dadrasnia (2013) reported that organic amendment is helpful in correcting polluted soil. The pH of the soil been more alkaline was as a result of the spent carbide reacting with water. Spent carbide is known to be composed of Ca, Mg, Si and Fe. (Table 2).

Three months after amendment (3 MAA) there was decrease in heavy metal content and total hydrocarbon content of the soil exception of 2.5%CND (carbide without digestate) and 0%CD (control experiment with digestate) which had increased Fe content in the soil. The control experiment that received digestate treatment (0%CD) was void of Cu, Cd, Cr, Pb, Ni and V, while 0%CND (control without digestate) had the presence of heavy metals in minute concentrations and THC was above 100 which was higher than that found in 2.5%CD (carbide with digestate). This reduction may be due to the presence and bioavailability of nutrient element present in the digestate as supported by the report of Joo et al. (2007) who observed that the addition of food waste compost result in an increase rate diesel fuel removal from soil. Also the high pH could also be a reason for the effective reduction of the total hydrocarbon content (THC) of the contaminated soil as microorganism is more effective in a slightly alkaline environment (Okoh, 2006).

The reduction in hydrocarbon contents may also have resulted from a number of processes including volatilization, diffusion and microbial degradation in a dissolved state (Kappeler and Wuhrmann, 1978; Jordan and Payne, 1980). These are all processes reported to be synergistically involved in natural attenuation (Ikhajiagbe and Anoliefo, 2011; Ikhajiagbe et al., 2013, 2014). The performance of such mechanisms of attenuation also depends, to a large extent, on improved soil. Apart from
improving water retention in sandy soil and promoting soil structure by increasing the stability of soil aggregates, soil amendments also enhances soil fertility by modifying the chemical, physical and biological properties of the soil (Vangronsveld and Chigsters, 1992). Maximum degradation efficiency is achieved through maintaining aeration and moisture if necessary and closely monitoring moisture content and temperature.

The impact of the various treatments on plant growth was also investigated. Reduction in plant growth may have been related with a number of factors including a decrease in total nitrogen, an element that is of utmost importance in plant growth and development. Results showed that the plants sown in 10%C (ND) had the best plant height (48.8 cm), compared to the control (41.5 cm). The effect of calcium carbide may not be farfetched. Comparing plant performance of those plants sown in 10% Carbide-amended oil-polluted soils, it was observed that plants never survived until soil was enhanced with nitrogen from substrate source in the form of digestates. Nitrogen (N) is an essential macro nutrient and is mostly deficient in agricultural lands. The present study showed nitrogen loss due to oil pollution (see Table 2). Nitrogen is also lost depending on the agricultural system and the environment, by leaching, erosion and runoff, or by nitrification. Banerjee and Mosier (1989) and Banerjee et al. (1990) reported that the application of a nitrification inhibitor is a promising approach to improve N management in agriculture; one of such inhibitors being acetylene from calcium carbide. Interest in the use of nitrification inhibitors stems from the fact that these materials inhibit or rather retard nitrification process in the soil and reduces the chances of N loss by various mechanisms and thereby enhances N uses by crops even under stress conditions. Volatilization of ammonia is another source of nitrogen loss. Freney et al. (1983) reported NH3-loss over soil with high pH. Higher pH values were reported in the study (also see Table 2). Nitrification inhibition of applied fertilizer N (in this case, applied as digestate) is thus desirable.

Sometimes the over-application of nitrogen sources may become injurious to plants. Addiscott et al. (1991) emphasized that the accumulation of nitrates in soils in excess of plant needs can adversely affect plant growth and leads to loss by denitrification and leaching. These losses contribute to low efficiency of fertilizer nitrogen used by crops (van Cleemput et al.,1981; Zhu et al., 1989; Sisworo et al., 1990), which in many cases lead to poor plant growth and death. This therefore underscores the importance of CaC2 in the regulation of these losses for improved crop growth. Patra et al. (2006) suggested that ammonia mono-oxygenase is reduced with reducing population of ammonia oxidizing bacteria during the slow release of acetylene (C2H2) from encapsulated CaC2. Enzyme activities would eventually be regarded in favour of C and N conservations.

Saleem et al. (2002) reported that CaC2 application at 90 kg ha⁻¹ enhanced horizontal expansion of plant, yield of green pods, number of green pods per plant, fresh and dry weights of shoot and root and internodes length of okra, while plant height decreased with increase in CaC2 application rate. Positive response of okra to calcium carbide application is also reported by Kashif et al. (2008).

The presence of chlorosis in T. occidentalis was seen in all treated experiments irrespective of the addition of carbide or digestate as at day 40, while the leaves of both control experiment were free of chlorosis. The chlorophyll content index (CCI) as at 40DAS showed that the digestate played a great role as the control experiment 0%CD (having digestate) had the highest CCI when compared to the treatment set-up. Likewise in all treatment set-up, those that received the digestate treatment had higher CCI than those without digestate CCI. This observation was supported by Agamuthu and Dadasrnia (2013) who reported that the addition of cow dung to crude oil contamination increased the total chlorophyll contamination Glycine max.

Increased vegetable yield in terms of number of leaves in the oil-polluted soils with the application of CaC2 is probably attributed to enhanced uptake of nutrients by the plant due to production of ethylene from CaC2 (Ahmad et al., 2004). Ahmad et al. (2004) also suggested that it may also be due to increase in root primordia to explore more volume of soil to acquire nutrients. Effects on plant root were however not investigated. Tanee and Ochekwu (2010) reported negative affects of CaC2 on fresh weight and dry weight yield of Zea mays Linn. (maize) and Arachis hypogea Linn. (groundnut). Nadeem et al. (2012) reported vegetative growth stage of potato showed remarkable effects on growth, yield and tuber quality on exposure to CaC2. The influence of nutrients on plant growth and development is well documented. Increase in N uptake by wheat may be due to nitrification inhibition action of CaC2 application. Acetylene released from calcium carbide in the soil environment might inhibit nitrification and fertilizer nitrogen remained in plant available form for a long time than usual.

**Conclusion**

The present study reaffirms the position that amendment of oil-polluted soils. It also provides information of the importance of carbide on the further improvement of plant growth performance in oil-impacted soils which are usually worsened with decreased nitrogen concentrations or low nitrogen use efficiencies. In the study, the source of nitrogen was waste digestate that would ordinarily be disposed of. This further underscores the call for value addition to biowastes. Rather than indiscriminately throw away waste, they could be converted into biofertilizers in the form of compost, and then used to improve the quality of contaminated soils; this also includes the spent carbide waste. Further research is also required to
thoroughly investigate impact on soil chemistry and plant metabolism as no information on the use of spent carbide for improve nitrogen use efficiency exists in literature, but encapsulated calcium carbide.

References
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