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Full Length Research Paper

Impact of calcium carbide waste dumpsites on soil chemical and microbial characteristics

Ihejirika CE[1*], Nwachukwu MI[4], Njoku-Tony RF[1], Ihejirika OC[2], Enwereuzoh UO[1], Imo EO[3], and Obenade M[5]

[1]Department of Environmental Technology,Federal University of Technology, Owerri
[2]Department of Public Health, Federal University of Technology, Owerri
[3]Department of Microbiology, Federal University of Technology, Owerri
[4]Department of Microbiology, Imo State University, Owerri, Nigeria
[5]Department of Geography and Environmental Science, University of Calabar, Nigeria

Abstract

Disposal of industrial solid wastes in the environment is a major environmental challenge. This study investigated the effects of calcium carbide waste dumpsites on soil quality. Soil samples were collected with hand auger from three different dumpsites at varying depths and made into composite samples. Samples were subjected to standard analytical procedures. pH varied from 10.38 to 8.28, nitrate from 5.6mg/kg to 9.3mg/kg, phosphate from 8.8mg/kg to 12.3mg/kg, calcium carbide reduced from 10 to 3%. Calcium carbide was absent in control soil samples. Bacterial counts from dumpsites ranged from 1.8 x 10^5 - 2.5 x 10^5cfu/g while fungal ranged from 0.8 x 10^3 - 1.4 x 10^3cfu/g. Bacterial isolates included *Pseudomonas* spp, *Flavobacterium* spp, and *Achromobacter* spp, while fungal isolates include *Penicillium notatum, Aspergillus niger,* and *Rhizopus stolonifer.* No organism was isolated from the dumpsites at soil depth of 0-15 cm, while there were isolates from other soil depths. Toxicity might be due to alkaline condition of the dumpsite. Calcium carbide might be bactericidal and fungicidal leading to cellular physiology, growth retardation, death, general loss of biodiversity and reduction of ecosystem processes. Detoxification of calcium carbide waste before disposal on soil might be the best option in management.

Keywords: Calcium carbide waste, Soil health, Denitrification, Toxicity, Biodiversity, Ecosystem processes.

INTRODUCTION

Generated wastes are disposed into the environment without adequate treatment. On entering into the soil, it leads to nutrient enrichment and the accumulation of toxic compounds in biomass and sediments (Dunbabin, 1992). Most of these infiltrated substances lead to the death of soil living biota. Nitrates and phosphates that are usually found in municipal waste dump sites promotes microbial growth while calcium carbide from spent carbide dump sites can lead to the death of microorganisms that supports plant growth hereby making it unsuitable for cultivation of plants.

Calcium carbide(CaC_2) is usually used in industrial acetylene production for welding tools and in chemical synthesis. It is also used in caving fuel acetylene, large spent carbide is usually left by some cavers anywhere in caves where the recharging of gas generators takes place and over the year this can result in substantial accumulation of such wastes such as carbide dumps (William et al., 2000).

On the other hand, calcium carbide as a nitrification inhibitor has been studied by a number of workers (Aulakh et al., 2001; Yascen et al., 2006). Due to its rapid reaction with water, it is mostly applied to soil in some encapsulated form so that a sustained supply of acetylene gas may be produced to inhibit the activity of

*Corresponding Author E-mail: ceihejirika@yahoo.com; Tel: +234 8037760837

ammonium oxidizing enzyme for a longer period. The problem of carbide disposal has a long history. By the present time, the use of carbide lamps is highly restricted in some countries such as Australia, USA, New Zealand and so on. However, such lamps are still used in many other countries and large carbides are been deposited in many soils. Reseach has shown that calcium carbide can lead to the death of all hatched larvae and also all microorganims that can support plant growth hereby making the soil unfavourable to plants growing within that area. According to Lavoic et al. (2002), spent calcium carbide waste is highly toxic but looses its toxicity within a short period of time.

According to Semikolennykh et al. (2012), in a study carried out by Agagabyan on spent carbide toxicity on microorganisms, a solution of waste at 0.5% concentration caused bacterial cell death within 10 minutes. It was shown that gram positive bacteria tend to be more resistant to spent carbide than gram negative bacteria. Toxic effect of spent calcium carbide on *Ptomaphagus hirtus* cave beetles eggs conducted by Peckin 1969 (Elliot, 2000), showed that it could cause the death of the larvae.

According to Semikolennykh et al. (2012), the reaction of calcium carbide with water creates acetylene:

$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$

That commonly-held view was substantiated by the fact that the waste's main chemical compound is calcium hydroxide – $Ca(OH)_2$, which reacts over time with atmospheric carbon dioxide to form non-toxic calcium carbonate (Semikolennykh et al., 2012). A comprehensive analysis of the spent carbide toxicity was carried out by Lavoie (1980) who conducted a series of *in situ* and *in vitro* experiments. It was shown that calcium carbide waste causes the death of most microorganisms within 10 minutes, even if applied at concentrations as low as 0.1% (waste:water = 1:1000).However, the number of microorganisms found under the waste in the cave floor was comparable with that occurring in the non-waste control area. This phenomenon was interpreted to be a result of the neutralization of spent carbide toxicity upon contact and reaction with atmospheric carbon dioxide. According to Lavoie (1980), the main cause of such toxicity was a high pH (about 11.2) of the waste. Lavoie (1980) experiments on neutralizing the waste demonstrated that its pH reduced from 11.2 to 6.3 within 25 days in a natural cave environment and within 10 days under forced additional aeration. The replicated experiment with the carbide waste neutralized to pH 6.3 demonstrated an absence of toxic effects to *E. coli* within a period of 60 minutes. The general conclusion by Lavoie (1980) was that the waste is highly toxic, but loses its toxicity within a short period of time, and that the toxic effect is manifested only within small areas of a cave.

However, Semikolennykh et al. (2012) research on air-exposed waste has shown that such waste does not change into calcium carbonate for at least a decade, and even over 13 years the pH of such waste remains strongly alkaline. Only dilution at a waste-to-water ratio of 1:1000 causes a decrease in pH sufficient for it to be harmless to the environment.

Calcium carbide waste acts as rich source of acetylene gas upon its reaction with water. Acetylene is an effective inhibitor of denitrification because it inhibits the activity of ammonia oxidizing enzyme involved in the nitrification process (Berg et al., 1992). However, reduced rate of nitrates in soil may result in N-fertilizer use efficiency. According to Frankenberger (2002), CaC_2 wastes have been used as denitrificator in soil.

The aim of this study was to investigate the impact of calcium carbide waste on the chemical and microbial characteristics of soil at calcium carbide waste dumpsite. This will enable proper understanding of the consequences of improper management of spent calcium carbide waste on soil health.

MATERIALS AND METHODS

Study area

Owerri, Imo State, Nigeria, lies between 5° 29' 0" North and 7° 2' 0" East. Nekede mechanic village falls under the geographical coordinates of longitude 7.04 – 7.06^{o}W and latitude 5.24 – 5.27^{o}N (Udebuani et al., 2011). It lies on an area of flat agricultural land converted to mechanic workshops, shops and homes, where some of the mechanic and their families live. This makes the area very busy with human activities.

Soil sample collection

Soil samples were collected by hand auger (2.5 cm diameter) from three different calcium carbide waste dump sites at depths of 0-15, 15-30 and 30-45cm; the sampling points were at Orji Mechanic Village, Orji, Nekede Mechnic Village Owerri, Umuguma Mechanic Village and a virgin land at Federal University of Technology, Owerri (FUTO) which was used as a control. Composite samples were made from samples from the dumpsites (33.3/33.3/33.3%) for different depths consecutively.

Chemical analyses

Determination of pH

Twenty grams of air dried soil samples were weighed into a 50mL beaker and 20mL distilled water was added and allowed to stand for 30mins. The solution was filtered and the filterate used to determine pH of soil sample. Hach pH meter was used to determine the pH. Meter was calibrated using pH calibration buffer solution for pH 4, 7 and 10. The electrode of the meter was dipped into the filtrate and the pH meter readings taken to the nearest 0.05unit.

Determination of phosphate

Phosphate was determined using Hach Spectrophotomer DR 2000. Ten grams of air dried soil sample was weighed into a 100ml beaker. The soil was treated with prepared phosphate extraction solution. Phosphate pillow was added to the Soil Extract. The concentration of phosphate in the sample was determined using DR spectrophotometer at 890nm. Distilled water containing phosphate pillow was used as bank to zero the instrument.

Determination of nitrate

Nitrate was determined using Hach Spectrophotomer DR 2000. Ten grams of air dried soil sample was weighed into a 100ml beaker. The soil was treated with prepared nitrate extraction solution. Nitrate pillow was added to the soil extract. The concentration of nitrate in the sample was determined using DR spectrophotometer at 500nm. Distilled water containing nitrate pillow was used as bank to zero the instrument

Determination of calcium carbide

Concentration of calcium carbide in the soil samples were determined using standard methodology by reacting the sample with water and measuring the volume of acetylene produced as an index of the calcium carbide in sample. In this method, carbide lantern with appropriate gauge to measure the percentage of acetylene produced was used for the test. During the test, 1 liter of water was placed in the upper chamber of the lantern and 20g of soil sample placed in the bottom. The screw in the apparatus adjusted the water flow into the bottom chamber. Acetylene production comes out from a pin hole in the middle. A meter gauge was used to measure the volume of acetylene produced which is proportional to the calcium carbide in the sample.

Microbiological analysis

Enumeration of hetrotrophic bacteria

Stock dilution of the water sample was prepared by measuring out 1mL of the water sample into 9ml of sterilized distilled water. The mixture were shaken vigorously for 60 seconds.; A 10-fold serial dilution was then carried out using sterile distilled water. One mL of each dilution from 10-4 to 10-6 were aseptically inoculated in triplicate for the bacteria count. Nutrient agar was the media used for the bacteria count.

A pour plate method of culture was used. Two un-inoculated plates were used as control. The culture plates were incubated at ambient temperature for 48 hours. At the end of incubation period, the plates were counted which involved counting the number of colony forming unit (cfu/mL) present in the plate using a tally hand counter. The colony forming unit per mile was calculated as follows:

cfu/ml = Number of colonies counted x dilution factor/volume of sample used

Enumeration of fungi

Enumeration of fungi was done using Sabouraud agar. Serial dilution of the sample was carried out as stated above. Sabouraud agar was used for the enumeration of the fungi in the sample. Pour plate method was used and the incubation temperature was 30^0C for 4days.

Isolation and Identification of bacteria

The associated bacteria and fungi were isolated and identified using microscopic biochemical test (Gram test, Catalase test, Nitrate Reduction Test, Galatine Hydrolysis and Starch Hydrolysis), and sugar fermentation (Glucose, Mannitol, Maltose, Inositol, Rafinols, and Mannose Fermentation) were used to identify bacteria isolates.

RESULTS

Results of chemical Analyses

The results of chemical analyses were presented in table 1.

pH varied from 10.38(0-15cm) to 9.40(15-30cm) and to 8.28(30-45cm in the composite soil sample, and varied from 5.42(0-15cm) to 5.38(15-30cm) and 5.66 (30-45cm) in the control soil sample.

The levels of nitrate content varied from 5.6mg/kg (0-15cm) to 7.4mg/kg (15-30cm) and 9.3mg/kg

Table 1. Variations of parameters at different depths of contaminated soil with control

Parameters	Dumpsite 0-15cm	Dumpsite 15-30cm	Dumpsite 30-45cm	Control 0-15cm	Control 15-30cm	Control 30-45cm
pH	10.4	9.4	8.3	5.4	5.4	5.7
Nitrate (mg/Kg)	5.6	7.4	9.3	15.9	13.4	11.5
Phosphate (mg/Kg)	8.8	10.5	12.3	49.6	20.4	21.3
Calcium Carbide (%)	10	8	3	Nil	Nil	Nil

(30-45cm) in the composite soil sample and from15.95mg/kg (0-15cm) to 13.40mg/kg (15-30cm) and 11.45mg/kg (30-45cm) in the control soil sample.

The phosphate content varied from 8.8mg/kg (0-15cm) to 10.5mg/kg (15-30cm) and 12.3mg/kg (30-45cm) in the composite sample and from 49.6mg/kg (0-15cm) to 20.4mg/kg (15-30cm) and 21.3mg/kg (30-45cm) in the control soil sample.

The concentration of calcium carbide reduced from 10 to 8% and finally to 3% at depths of 0-15, 15-30 and 30-45cm respectively in the composite sample and was completely not detected in the control soil sample. Calcium carbide was absent in control soil samples.

Results of microbiological analyses

On physical observation at the spent calcium carbide dumpsite, there was no macroscopic or visible growth of any plants. The entire soil within the area of dumpsites did not support any grasses, shrubs and higher plants. The results of microbial analyses are as shown in table 2 and table 3. Bacterial counts from dumpsites ranged from 1.8×10^5 - 2.5×10^5cfu/g while fungi ranged from 0.8×10^3- 1.4×10^3cfu/g. Bacterial isolates include *Pseudomonas s*pp, *Flavobacterium* spp, and *Achromobacter* spp, while fungal isolates include *Penecillium notatum, Aspergillus niger* and *Rhizopus stolonifer.* No organism was isolated from the dumpsites at soil depth of 0-15 cm, while *Pseudomonas s*pp, *Flavobacterium* spp, *Penecillium notatum* and *Aspergillus niger* were isolated from dumpsites at soil depths of 15-30 and 30-45cm. All these isolates were present at all depths of the control soil sample.

DISCUSSION

The pH of the dumpsite was alkaline against the acidic pH of the control. The alkalinity was gradually reducing as the depth of the soil increased. This was in accordance with the work of Lavoie (1980), who observed a high alkaline pH (about 11.2) of the waste. Moreover, the reduction in the pH might be due to possible dilution of the contaminant down the soil depth.Semikolennykh et al. (2012) stated that on dilution of waste-to-water ratio of 1:1000 causes a decrease in pH sufficient for it to be harmless to the environment. On the surface, the pH can remain unchanged and strongly alkaline for many years.

There was notable reduction in the concentration of nitrate in the contaminated soil samples. However, the process might not be clear, acetylene gas that is the product of reaction of calcium carbide with water might inhibit nitrification process in soil (Berg et al., 1992). Nitrate will be loss more in high concentrated areas of calcium carbide waste than deeper levels of the soil. According to Frankenberger (2002), CaC_2 wastes have been used as denitrificator in soil.

Phosphate concentration in the contaminated sites was higher than that of nitrates. However, its availability might be influenced by the presence of nitrate in the soil. Since water is the solvent for phosphate and nitrate in the soil, its availability in the soil for plant growth might obey the Redfield ratio (Ihejirika et al., 2011). If the Redfield ratio is 16:1, P is most likely the limiting factor for plant growth; lower ratio indicates that N is of great importance. This corroborates the works of Redfield et al. (1963), and Hodgkiss and Lu (2004). In some fresh water environments, particularly in the tropics and subtropics, N has been found to be the primary limiting nutrient for biomass production, due in large part to excessive P load and long growing seasons (Xiao-e et al., 2008).

Calcium carbide concentration in the contaminated to top soil was higher than at other depths possibly due to dilution effects. Calcium carbide might be more toxic at the contaminated top soil more than other depths. Experiment carried out by Lavoie (1980) showed that calcium carbide waste causes the death of most microorganisms within 10 minutes, even if applied at concentrations as low as 0.1% (waste:water = 1:1000).At the range of 10% to 3% of calcium carbide in contaminated soil samples, it might be bactericidal and fungicidal. As unicellular organisms, the effect of calcium carbide on any soil living biota might lead to destruction

Table 2. Microbiological count of samples at different soil depths

Total Microbial Count	Dumpsite soil sample			Control Sample		
	0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
THBC (x 10^6cfu/g)	0.00	0.18	0.25	3.88	3.13	3.24
THFC (x 10^4cfu/g)	0.00	0.08	0.14	2.21	3.14	2.32

Table 3. Distribution of microbial isolatesat different soil depths

SN	Names of Microbial Isolates Identified	Composite contaminated soil			Control		
		0-15cm	15-30cm	30-45cm	0-15cm	15-30cm	30-45cm
1	*Pseudomonas* spp (Bacteria)	-ve	+ve	+ve	+ve	+ve	+ve
2	*Flavobacterium*spp (Bacteria)	-ve	+ve	+ve	+ve	+ve	+ve
3	*Achromobacter*spp (Bacteria)	-ve	-ve	-ve	+ve	+ve	+ve
4	*Penecilliumnotatum* (Fungi)	-ve	+ve	+ve	+ve	+ve	-ve
5	*Aspergilus niger* (Fungi)	-ve	+ve	+ve	+ve	+ve	+ve
6	*Rhizopus stolonifer* (Fungi)	-ve	-ve	-ve	+ve	+ve	-ve

of cellular physiology, cell lysis, growth retardation, death (Elliot, 2000) and general loss of biodiversity. At high concentrations in the soil, calcium carbide will bring about alkaline condition that is the major cause of toxicity (Lavoie, 1980). Calcium carbide toxicity might reduce with time due to its possible oxidation to calcium hydroxide that is none toxic. This loss of toxicity under aeration might take up to 25 days (Lavoie, 1980) or decades (Semikolennykhet al.,2012) to actualize.

Physical observation of no plants growth and the accompanying no growth of microbes in the contaminated soil samples at 0-15cm soil depth might be due to the toxicity effects on organisms by higher concentration of calcium carbide waste.Semikolennykh et al. (2012) reported the toxicity of spent carbide on microorganisms. It was observed that a solution of waste at 0.5% concentration caused bacterial cell death within 10 minutes, which implied that concentrations 8-10% in soil samples in this study, might cause greater death of microbes. This might result to reduction of microbial diversity and affect ecosystem processes. A study by Eckford et al. (2002) supported this with the observation that *Pseudomonas* spp are involved in nitrogen fixation in the soil and their death in soil will affect nitrogen cycle. At higher depths, the observed growths of organisms might be due to reduced toxicity effects due to decreased concentration of calcium carbide and possible succession of microbes (KaplanandKitts, 2004).

The presence of fungal specie can be attributed to their wide distribution in soils and their association with buried and decaying plant materials (Landeret al., 2001).

CONCLUSION

Untreated calcium carbide waste alters the pH of the soil, is toxigenic and can affect ecosystem processes. Treatment of calcium carbide waste by oxidation (aeration) will reduce its effects on soil health.

REFERENCES

Aulakh MS, Khera TS, Doran JW, Kuldip S, Bijay S (2000). Yields and nitrogen dynamics in a rice wheat system using green manure and inorganic fertilizer. Soil Sci. Soc. Am. J.,Vol. 64, pp. 1867-1876

Berg HC, Brown DA (1992). Chemotaxis in Escharichia Coli analysed by- dimensional tracking.Nature. J. Emerg Med, Vol. 239, No. 5374, pp. 500 – 504.

Dunbabin JS (1992). Potential use of constructed wetlands for treatment of industrial wastewater containing metals effluent and urban pollution control manual. pp.79-82.

Eckford R, Cook FD,Saul D, Aislabie J, Foght J (2002). Free-Living Heterotrophic Nitrogen-Fixing Bacteria Isolated from Fuel-Contaminated Antarctic Soils. Appl Environ Microbiol. 68(10): 5181–5185.

Elliot WR (2000). Conservation of the North American cave and karst biota. In. Wilkens H, Culver DC, Humphry WF (eds). Suntererranean Ecosystems, pp. 665-689

Frankerberge WT, Arshad M (2002). Ethylene: Agricultural sources and Applications. KluwerAcademic/ plenum publishers, New York, U.S.A.pp. 542-550

Hodgkiss IJ, Lu SH (2004). The effects of nutrients and their ratios on phytoplankton abundance in Junk Bay, Hong Kong. Hydrobiologia.Vol. 512, No.1-3, pp. 215-229.

Ihejirika CE, Ogbulie JN, Emereibeole EI, Ihejirika OC, Amaku GE, Mgbeahuruike L (2011). Seasonal influences on levels and eutrophication potential of nutrients in Imo River, Nigeria.Vol. 1, No. 4, pp. 16-21

Kaplan CW, Kitts CL (2004). Bacterial Succession in a Petroleum Land Treatment Unit,Appl. Environ. Microbiol.Vol. 70,No. 3, pp.1777-1786

Lander F, Meyer HW, Norn S (2001). Serum IgE specific to indoor moulds, measured by basophil histamine release, is associated with building-related symptoms in damp buildings. Inflamm Res, Vol. 50, No. 4, pp. 227-231

Lavoic YP, Teng TP, Chang TK (2002). Multivariate analysis of soil heavy metal pollution and landscape in Changhua Country in Taiwan. Landscape Urban Plan., Vol. 62, pp. 19 – 35

Lavoie KH (1980). Toxicity of carbide waste to heterotrophic microorganisms in caves.- Microbial Ecology, Vol. 6, No. 2, pp. 173–179.

Redfield AC, Ketchum BH, Richards FA (1963). The influence of organism on the composition of seawater. In: Hill, M.N., editor. *The sea.* Wiley- Interscience, New York. Vol. 2, pp. 26-27.

SemikolennykhAA, Rahleeva AA, Poputnikova TB (2012).Spent carbide waste retains toxicitylong term after disposal in caves and mines. Acta carsologica Vol. 41, No. 1, pp.129–137

Udebuani AC, Okoli CG, Okoli IC, Nwigwe HC, Ozoh PTE (2011). Assessments of the volume and disposal methods of spent engine oil generated in Nekede mechanic village, Owerri, Nigeria. Report and Opinion, Vol. 3, No.2, pp. 31-36.

William R (2000). Discovery and Identification of Calcium Carbide in the U.S.A. J. Clin. Endocrinol Metab, Vol. 43, pp. 64-67.

Xiao-e Y, Xiang W, Hu-lin H, Zhen-li H (2008). Mechanism and assessment of watereutrophication. J. Zhhejiang Univ. Sci.B.,Vol. 9, No. 3, pp. 197-209

Yaseen M, Arshad M, Khalid A (2006). Effects of acetylene and ethylene gases released from encapsulated calcium carbide in growth and yield of wheat and cotton. Pedobiologia, Vol. 50, pp. 405-411

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