International Journal of Botany

ISSN: 1811-9700

science alert

ANSInet
an open access publisher
http://ansinet.com

International Journal of Botany 3 (4): 385-389, 2007
ISSN 1811-9700

Heavy Metal Contents of Maize (*Zea mays* L.) Grown in Soil Contaminated with Crude Oil

O.M. Agbogidi, P.G. Eruotor, S.O. Akparobi and G.U. Nnaji
Faculty of Agriculture, Delta State University, Asaba Campus, Nigeria

Abstract: This study investigated the effects of soil contaminated with crude oil on the heavy metal contents of maize. The study was conducted in Asaba and Ozoro locations of Delta State. Open-pollinated AMATZBR w maize variety was used. The experiment was laid out in a split-plot design replicated four times. Five crude oil concentrations (0, 5.2, 10.4, 20.8 and 41.6 mL) applied five weeks after planting (5 WAP) constituted treatments. The study locations formed the main plots and the oil levels, the sub-plots Maize grain was harvested at 14 WAP, shelled and analysed for heavy metal contents. Soil physical properties were also analysed from composite soil samples. The results showed that oil treatment had no significant ($p \geq 0.05$) effects on soil physical properties. Significant ($p \leq 0.05$) differences were, however, observed in the heavy metal contents (including iron, zinc, chromium and manganese) of crude oil contaminated soils and the maize seeds harvested there when compared with those harvested from the uncontaminated sub-plots. The present study has demonstrated that crude oil contamination of soil can lead to a gradual heavy metal build-up which, when absorbed are capable of making the maize cobs and leaves potentially toxic and harmful to man and livestock if consumed as food.

Key words: Crude oil, soil contamination, heavy metal contents, maize

INTRODUCTION

Nigeria is a major producer and exporter of crude petroleum oil as well as an important agricultural nation in the West African sub-region (Agbogidi and Nweke, 2005a; Agbogidi *et al*., 2005a). The continuous exploration, production, processing of crude oil and its transportation exposes the environment to constant threat of oil pollution (Agbogidi *et al*., 2005a). Oil pollution, whether acute or chronic, has deleterious effects on agricultural lands and hence significant effects on plant growth (Agbogidi *et al*., 2005b, 2006, 2007). Atuanya (1987) and Benka-Coker and Ekundayo (1995) reported that oil pollution tends to change the physical, biological and chemical properties of soil thus, affecting plant growth and subsequent yields. Oil pollution has been reported to create some conditions in soils, which make some essential mineral nutrients unavailable to plants and make some non-essential ones either readily available or cause them to rise to a toxic level (Udo and Oputa, 1984; Atuanya, 1987; Ekundayo and Obuekwe, 1997; Siddiqui and Adams, 2002). Heavy metal pollution occurs when heavy metals are introduced into the environment either naturally or by man's activities resulting in an unfavourable change in such a way that the safety and welfare of any living organism is endangered.

Although some research works have been carried out on oil pollution on crop plants: soyabean (Udo and Oputa, 1984), melon (Anoliefo, 1991), hot pepper and tomatoes (Anoliefo and Vwioko, 1995), fluted pumpkin (Asuquo *et al*., 2002), okra (Agbogidi and Nweke, 2005b; Agbogidi *et al*., 2007), there is paucity of information on the effects of crude oil contaminated soil on the heavy metal content of maize in Delta State. Maize (*Zea mays*) is an important staple crop in Nigeria (Obi, 1991). It is one of the staple foods consumed by the teaming population of Nigeria in large amount. Maize ranks third in the world production of cereal following wheat and rice (FAO, 2002). It is used as feed for livestock and a principal raw material for many industrial products (FAO, 2002; Agbogidi *et al*., 2007). A study on the effects of crude oil on maize in Delta State is necessary as it will provide information on the efficient management of crude oil contaminated soils in maize growing areas of the State. The present study was designed to evaluate the heavy metal contents of maize grown in crude oil contaminated soil with a view to determining the risk, if any, to the consumers of maize grown in crude oil impacted soils.

MATERIALS AND METHODS

Study locations: The study was carried out in Asaba and Ozoro locations in Delta State. Asaba (latitude: 06° 14′N, longitude: 06° 49′ E, temperature: 28±6°C, rainfall 1505-1849 mm, relative humidity: 69-80% and monthly

Corresponding Author: O.M. Agbogidi, Faculty of Agriculture, Delta State University, Asaba Campus, Nigeria

sunshine: 4.8 bars), is located in the rainfall agro-ecological environment (Asaba Meteorological Station, 2003). Ozoro lies between latitude 6° 13′E and longitude: 5°33′N and it is under the rainforest ecological zone of Delta state. Ozoro experiences double peak periods of rainfall between June/July and September/October, respectively. The annual rainfall is 2800 mm while that of the temperature is 31°C and relative humidity 76-90% (Anonymous, 2003). The experiment took place between April and September 2003 and 2004 cropping seasons.

Experimental materials and design: NPK fertilizer (20-10-10) used for the study was obtained from the Delta State Agricultural Procurement Agency, (DAPA) Ibusa, Delta State. It was applied prior to planting based on the analytical information of the soil nutrient status. The crude oil used (with specific gravity of 0.8334 g cm^{-3} and AP1 gravity of 34.2897) was obtained from the Nigerian National Petroleum Corporation (NNPC), Warri. The maize (AMATZBR w) was sourced from the International Institute of Tropical Agriculture (IITA), Ibadan, Oyo State.

The experimental design was a split-plot arrangement replicated four times. Location of study formed the main plots while the crude oil levels were allotted the sub-plots. A sub-plot (2.8125 m^2) contained 24 stands of maize. Planting was done in 2003 and 2004 cropping seasons in both locations. Between row spacing was 75 cm and within row was 25 cm. Five crude oil levels (0, 5.2, 10.4, 20.8 and 41.6 mL) were applied to soil (ring application) at five Weeks After Planting (WAP). Ears were harvested at 14 WAP and mechanically shelled. The maize seeds were ground and each of the meals of the maize samples were dried, weighed and a known amount ashed and then wet digested using nitric acid. The digests were later analysed for heavy metals by atomic absorption spectrophotometry using the standard addition method. Soil analysis was also carried out to determine soil physical properties. The analysis was carried out at the Nigerian Institute for Oil Palm Research (NIFOR) near Benin, Edo State. Concentration of heavy metals including iron, zinc, copper, manganese, lead, chromium, nickel and cadmium was determined after digestion of soil samples with hydrofluoric acid and perchloric acid. The concentrations of the elements were read by means of an atomic absorption spectrophotometer. Data collected were subjected to analysis of variance and the significant means were separated with the Duncan's multiple range tests using SAS (1996).

RESULTS

Particle size analysis of Anwai and Ozoro locations showed that the soils are of sand textural class, with silt and clay contents ranging from 0.3 to 3.4 (Table 1). Treatments had no significant effect ($p \geq 0.05$) on soil physical properties. However, visual observation showed that plots treated with crude oil reduced water infiltration and percolation in the soil. This resulted in water accumulating in small pools. Air-drying of the crude oil treated soils took relatively longer time. On drying, the soil gave a cemented waxy appearance which more or less repelled or resisted water/re-wetting.

There was a build-up of heavy metals in the soils contaminated with crude oil. Soil contents of Fe, Zn, Cu, Mn, Pb, Cd, Cr and Ni were significantly ($p \leq 0.05$) higher in soils contaminated with crude oil when compared with the control sub-plots (Table 2). The maize seeds analyses also showed significantly higher amounts of heavy metals when compared with those grown in the uncontaminated soils at the 5% probability level (Table 3).

Table 1: Effect of different crude oil levels on some soil physical properties at Asaba and Ozoro locations

	Particle size distribution (%)					
Crude oil levels (mL)	Clay	Silt	Sand	Texture	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})
Asaba location						
0	3.4a	2.1a	94.5a	Sand	1.37a	2.74a
5.2	3.1a	0.9a	96.0a	Sand	1.36a	2.72a
10.4	2.8a	0.8a	96.4a	Sand	1.35a	2.70a
20.8	3.2a	0.7a	96.1a	Sand	1.34a	2.69a
41.6	2.9a	0.6a	96.5a	Sand	1.33a	2.67a
Ozoro location						
0	3.4a	1.1a	95.5a	Sand	1.37a	2.75a
5.2	3.2a	0.7a	96.1a	Sand	1.36a	2.73a
10.4	2.6a	1.1a	96.3a	Sand	1.35a	2.71a
20.8	2.1a	0.3a	97.6a	Sand	1.34a	2.60a
41.6	1.7a	0.4a	97.9a	Sand	1.33a	2.66a

Means in the same column with same letter(s) are not significantly different ($p \geq 0.05$), using DMRT

Table 2: Heavy metal content (mg kg^{-1}) of soils under different crude oil treatments

Crude oil level in soil (mL)	Heavy metals Fe	Zn	Cu	Mn	Pb	Cd	Cr	Ni
Asaba location								
0	0.68d	0.49d	0.05c	0.03d	0.03d	0.86c	3.10e	2.23e
5.2	0.84c	0.78c	0.09c	1.58c	0.06cd	0.90c	4.62d	4.30d
10.4	1.93bc	0.89c	0.12b	3.50b	0.09b	1.12c	8.00c	6.00c
20.8	2.45b	1.48b	0.15ab	3.92ab	0.15ab	1.15b	12.60b	8.80b
41.6	3.01ab	1.73a	0.18a	4.53a	0.24a	1.26a	15.42a	11.46a
Ozoro location								
0	1.09c	0.84c	0.07c	0.41d	0.05cd	0.71d	4.20d	2.46e
5.2	1.89bc	0.95c	0.10c	1.62c	0.08c	0.82d	5.64d	3.96d
10.4	2.74b	1.31b	0.13b	2.98bc	0.10b	0.98bc	7.96c	6.24c
20.8	2.98ab	1.56a	0.16ab	3.84ab	0.17ab	1.10c	11.80b	8.61b
41.6	3.76a	1.76a	0.19a	4.41ab	0.25a	1.16b	14.21a	12.00a

Means in the same column with same letter(s) are not significantly different ($p \leq 0.05$), using DMRT

Table 3: Heavy metal content (mg kg^{-1}) of maize seeds as affected by different crude oil levels in Asaba and Ozoro

Crude oil levels (mL)	Heavy metals Fe	Zn	Cu	Mn	Pb	Cr	N_i	Cd
Asaba location								
0	20.01d	60.50d	19.42d	67.02d	2.45e	1378.00e	1.96d	10.40d
5.2	21.42d	61.50d	22.36c	68.51c	3.13d	19.55d	2.06d	12.42d
10.4	23.06c	62.94c	23.89c	70.10b	5.82c	21.08c	4.02c	13.86c
20.8	26.89b	67.62b	25.62b	72.42b	6.94b	24.24b	5.96b	15.92b
41.6	29.42a	69.78a	27.81a	73.34a	8.46a	25.86a	8.10a	17.61a
Ozoro location								
0	19.65d	60.60d	18.50d	67.20d	3.42d	14.02e	2.20d	10.62d
5.2	20.84d	63.51c	20.62c	68.61c	4.60d	16.69d	3.84c	11.10d
10.4	23.01c	63.68c	22.78c	69.73b	5.90c	18.46d	5.42b	13.49c
20.8	25.61b	66.94b	24.64b	72.84b	7.02b	23.48b	5.98b	16.26b
41.6	27.96b	68.87a	26.86a	74.95a	8.87a	26.63a	7.61a	17.84a

Means in the same column with same letter(s) are not significantly different ($p \geq 0.05$), using DMRT

DISCUSSION

The non significant ($p \leq 0.05$) effects of crude oil application on soil physical properties in both locations studied may be due to the relatively low C:N. content of the crude oil treatment of the soil sample. Low C:N content of treatment materials may not have much influence on soil particle size distribution, bulk density and porosity since such materials are rapidly mineralised to release their nutrient components by soil organisms (Nnaji *et al*., 2005). However, cultivation of land and soil management practices adopted in the process of crop production may tend to lower the total pore space (Udo and Ogunwale, 1986) compared to that usually associated with a decease in organic matter content and as a consequent lowering of granulation. Similar results of non significant influence of crude oil on soil texture, bulk density of porosity had been observed by Asuquo *et al.* (2002).

The observed build-up of heavy metals with increasing level of oil supports the findings of Udo and Oputa (1984) and Ekundayo and Obuekwe (1997). These heavy metals present in the oil polluted soils, when absorbed by plants are capable of making the maize cobs and leaves potentially toxic and harmful to man and livestock if ingested or consumed as food (Ogri, 1998). This finding is in agreement with the report of Benson and Ebong (2005) on vegetables. Similarly, heavy metal accumulation in plants may lead to poor growth resulting in yield reduction. Lead and cadmium for example have been reported by Epstein (1972) to prevent mineral uptake by either synergistic or antagonistic reactions.

Although the amounts of these metals found in the soil samples were below lethal doses than those given by FAO (1976 and 2002), with gradual and steady deposition of such heavy metals in the soils, it may build-up to toxicity level. Charman and Murphy (1992) and Sherertz (1998) noted that because some components of crude oil are highly lipophilic, even small amounts entering the environment accumulate in organisms as a result of gradual and steady build-up. Possible bio-accumulation of the metal in the liver and kidney of man and his animals arouses a significant interest since man has the ability of bio-concentrating small doses of deleterious chemicals in his liver and kidney such that harmless quantities of poisonous chemicals would eventually build-up to dangerous levels. Heavy metals contents from both the contaminated and uncontaminated soils still fall below the critical values (Fe 40 ppm, Zn 43 ppm, Cu 36 ppm, Mn 48 ppm, Pb 140 ppm, N_i35 ppm, Cr 100 ppm and Cd 39 ppm) recommended by FEPA (2002).

Despite uptake of heavy metals by the maize plants, their low residues in soils were still higher compared to the control sub-plots. Generally, metals tend to accumulate in the clay fraction of the soil because clay-sized particles have a large number of ionic binding sites due to a higher amount of surface area (Epstein, 1972; Garcia *et al*., 1979). Epstein (1972) further maintained that metals could be tightly bound to organic matter content of the soil, which is gradually released during the process of mineralisation. Singh and Mishra (1987) reported that heavy metals retard seedling growth in rice and corn. Similar finding has been reported by Khan and Frankland (1983) for radish. The increase in the heavy metal contents of maize seeds is attributed to the increase availability of such cations in soil due to the anaerobic reducing environments caused by the oil in the soil. The high content of Mn in the plant tissues gives an indication of Mn toxicity (Badoglio and Stumm, 1994; Cobb *et al*., 2000) with time. Black (1957) and FMANR (1990) had earlier reported that as little as 4 ppm Mn caused yield depression while Adams and Ellis (1960) observed that gas-saturated soil contained over 60 ppm of exchangeable manganese ions and 120 ppm of exchangeable ferrous ions. The presence of these heavy metals in maize plant could induce yield reductions. Benson and Ebong (2005) reported that the poor growth of crops in higher levels of oil treatment was due primarily to the toxic effects of heavy metals or mineral uptake.

CONCLUSIONS

The study has demonstrated that crude oil contamination can lead to gradual heavy metal build-up in the soil and consequently, a significant increase in the heavy metal contents of maize grown in such soils. The poor soil conditions following oil application may be due to sub-optimal soil aeration and an increased demand of oxygen caused by increased population of oil decomposing microbes attracted to the soil as a result of the contamination.

From this study, it is recommended that Agronomists and Food Scientists need to conduct further research on the effects of growing other food crops in oil-contaminated tropical soils and monitoring the concentration of the oil pollutants, by-products and heavy metals in the plant tissues so that a reliable database can exist on how such heavy metals affect food safety, grain storage and spoilage problems in the rainforest zone of sub-Sahara African countries including Nigeria. Research on the combined application of crude oil, wastes and other organic amendments could also be carried out to determine how such amendments could help in the degradation of heavy metal content of the crude oil.

REFERENCES

Adams, R.S. and R. Ellis, 1960. Some physical and chemical changes in the soil brought about by saturation with natural gas. Soil Sci. Soc. Am. Proc., 24: 41-44.

Agbogidi, O.M. and F.U. Nweke, 2005a. Effects of crude oil polluted soil on the performance of okra (*Abelmoschus esculentus* L.) Moench in Delta State. Afri. J. Nat. Sci., 8: 31-35.

Agbogidi, O.M. and F.U. Nweke, 2005b. Impact of Gas Flaring on the Growth and Yield of Okra (*Abelmoschus esculentus* L.). Moench in Delta State. In: Proceedings of the 39th Annual Conference of the Agricultural Society of Nigeria Held at the University of Benin, Benin City, 9th-13th October, 2005. Orheruata, A.M., S.O. Nwokoro and G.N. Asumugha (Eds.), pp: 231-232.

Agbogidi, O.M., B.C. Okonta and D.E. Dolor, 2005a. Socio-economic and environmental impact of crude oil exploitation and production on agricultural production: A case study of Edjeba and Kokori communities in Delta State of Nigeria. Global J. Environ. Sci., 4: 171-176.

Agbogidi, O.M., F.U. Nweke and O.F. Eshegbeyi, 2005b. Effects of soil pollution by crude oil on seedling growth of *Leucaena leucocephala* (Lam. De Witt). Global J. Agric. Sci., 4 (In Press).

Agbogidi, O.M., S.O. Akparobi and P.G. Eruotor, 2006. Yields of maize (*Zea mays* L.) as affected by crude oil contaminated soil. Am. J. Plant Physiol., 1: 193-198.

Agbogidi, O.M., P.G. Eruotor, S.O. Akparobi and G.U. Nnaji, 2007. Evaluation of crude oil contaminated soil on the mineral nutrient elements of maize (*zea mays*). J. Agron., 6: 188-193.

Anoliefo, G.O., 1991. Forcados blend crude oil effects on respiratory mechanism, mineral element composition and growth of *Citrullus vulgaris* Schead. Unpublished Ph.D Thesis, UNIBEN, Benin-City, pp: 293.

Anoliefo, G.O. and D.E. Vwioko, 1995. Effects of spent lubricating oil on the growth of *Capsicum annum* (L.) and *Lycopersicon esculentum* (Miller). Environ. Pollut., 88: 361-364.

Anonymous, 2003. National Meteorological Report. In: Meteorological Bulletin 2003. Asaba Meteorological Station, Lagos, Nigeria.

Asuquo, F.E., I.J. Ibanga and N. Idungafa, 2002. Effects of Qua Iboe (Nigerian) crude oil on germination and growth of okro (*Abelmoschus esculentus* L.) and fluted pumpkin (*Telfairia occidentalis* L.) in the tropics. J. Environ. Pollut. Health, 1: 31-40.

Atuanya, E.I., 1987. Effect of waste engine oil pollution on physical and chemical properties of soil: A case study of waste oil contaminated Delta soil in Bendel State. Nig. J. Applied Sci., 5: 155-176.

Badoglio, A. and S. Stumm, 1994. Behaviour of Metal in Soil and Ground Water Pollution. In: Fundamental Risk Assessment and Legislation in Soil and Environment. Alexander, J.B. (Ed.), Scope Vol. 4. 1994.

Benka-Coker, M.O. and J.A. Ekundayo, 1995. Effect of an oil spill on soil physico-chemical properties of a spill site in the Niger Delta area of Nigeria. Environ. Monitor. Assess., 36: 93-104.

Benson, N.U. and G.A. Ebong, 2005. Heavy metals in vegetables commonly grown in a tropical garden ultisol. J. Sustainable Trop. Agric. Res., 16: 77-80.

Black, C.A., 1957. Soil-Plant Relationship. John Wiley and Sons Inc., New York.

Charman, P.E. and B.W. Murphy, 1992. A Soil Conservation Handbook for New South Wales in Soils: Their properties and management. Sydney University Press, Sydney.

Cobb, G.P., K. Sands, M. Waters, B.G. Wixson and E. Dorward-King, 2000. Accumulation of heavy metals by vegetables grown in mined wastes. Environ. Toxicol. Chem., 19: 600-607.

College of Agriculture Meteorological Station, 2003. Ozoro, Delta State, 2003.

Ekundayo, E.O. and C.A. Obuekwe, 1997. Effects of oil spill on soil physico-chemical properties of a spill site in a typic paledult of Midwestern Nigeria. Environ. Monitor. Assess., 45: 209-221.

Epstein, E., 1972. Mineral Nutrition of Plants: Principle and Perspectives. John Wiley and Sons, New York.

FAO, 1976. A framework for land evaluation. FAO Bulletin 32, FAO/UNESCO, Rome.

FAO, 2002. World Agriculture: Towards 2015/2030. Summary report, Rome.

FEPA (Federal Environmental Protection Agency), 2002. Review of environmental guidelines and standards for the petroleum industries in Nigeria (EGASPIN). Issued the Department of Petroleum Resources, Lagos, pp: 44.

FMANR (Federal Ministry of Agriculture and Natural Resources), 1990. Literature on soil fertility investigations in Nigeria. A Bulletin Produced by the Federal Ministry of Agriculture and Natural Resources, Lagos, pp: 281.

Garcia, W.J., C.W. Blessin, H.W. Sandford and C.E. Inglett, 1979. Translocation and accumulation of seven heavy metals in tissues of corn plants grown on sludge-treated strip-mined soil. J. Agric. Food Chem., 27: 1088-1094.

Khan, D.H. and B. Frankland, 1983. Effects of cadmium and lead on radish plants with particular reference to movement of metals through soil profile and plant. Plant and Soil, 70: 335-345

Nnaji, G.U., S.C. Mbagwu and C.A. Asadu, 2005. Changes in Physical Properties of Soil under Cassava Monocropping and Organic Waste Amendments. In: Proceedings of the 19th Annual Conference of Farm Management Association of Nigeria (FAMAN) held in Delsu, Asaba Campus, Delta State, Between 18th and 20th, October, 2005. Ogisi, O.D., P.B. Okunneye and W.J. Oyaide (Eds.), pp: 374-377.

Obi, I.U., 1991. Maize: Its Agronomy, Diseases, Pests and Food Values. Optimal Computer Solutions Ltd., Enugu.

Ogri, O.R., 1998. Environmental problems associated with livestock production in tropical Africa. The Environmentalist, 19: 137-143.

SAS (Statistical Analytical System) 1996. User's Guide. Statistics Version, Raleigh, N.Y, USA.

Sherertz, P.C., 1998. Petroleum products. A Bulletin Released by Virginia Department of Health, Richmond Virginia, pp: 2.

Siddiqui, S. and W.A. Adams, 2002. The fate of diesel hydrocarbons in soils and their effect on the germination of perennial ryegrass. Environ. Toxicol., 17: 49-62.

Singh, K.K. and L.C. Mishra, 1987. Effects of fertilizer factory on soil and crop productivity. Water Air Soil Pollut., 33: 309-320.

Udo, E.J. and C.O. Oputa, 1984. Some studies on the effect of crude oil pollution of soil on plant growth. J. Biol. Applied Chem., 29: 3-14.

Udo, E.J. and J.A. Ogunwale, 1986. Laboratory Manual for the Analysis of Soil, Plant and Water Samples. University of Ibadan Press, Ibadan.