The function of Acacia species on soil content of TOC, TDN and Microorganisms activity (SR) in the case of soil contamination with DU

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ABSTRACT

Environmental contamination by depleted uranium led to increasing radioactive waste containing uranium in the environment and especially in the soil. These contamination have severe negative biological effects on soil contents of microorganisms, organic materials, Total organic carbon (TOC), and soil total dissolve nitrogen (TDN).

In order to investigate the effects of Uranium on the TOC, TDN and microorganisms activity in the soil planted with Acacia species, the research designed with two species of Acacia (Acacia albida and A. nilotica), and five concentrations of uranium (0-500 mg.kg\(^{-1}\) soil) as Uranyl nitrate solutions (UO\(_2\)(NO\(_3\))\(_2\)). Uranium concentration is highly significant affected TOC in the soil of A. albida, whereas there is no effect of uranium on A. nilotica. Soil treatment with uranium, Total organic matter (TOM) decrease gradually by increasing uranium concentration in the soil in both species. Also, TDN decreased highly significantly in A. nilotica and significantly in A. albida with the increasing of uranium concentration. TOC and TDN was higher in soil planted with A. albida than that in soil of A. nilotica significantly, but A. nilotica more affected with uranium pollution of TN quantity in soil than A. albida.

Microbial soil activities affected negatively highly significant with uranium treatment especially at 200 and 500 mg.kg\(^{-1}\) in the soil of the two species.

Introduction:

Environmental contamination caused by depleted uranium due to the development of nuclear science and technology as well as used in military applications, has led to increasing radioactive waste containing uranium, and disposed in the environment especially in the soil. These contamination have severe negative biological effects on important groups of the soil food web, soil contents of microorganisms and organic materials (Curry and Good 1992). High concentrations of uranium pollution has been detected in many regions of Iraq due to the military operation in 1991 and 2003 (Al-Azzawi 2006). The pollution with DU caused harmful chemicals, radioactive and toxic pollutants which considered the biggest soil health threat we face today (Cohen 1990). Little attention was given to environmental matters and considerable pollution as well as environmental degradation occurred by depleted uranium, especially the soil and climate change.

The by-product of uranium enrichment, where the fissile isotope U\(^{235}\) is artificially concentrated for use as nuclear fuel or weapons, is depleted uranium (DU). Depleted uranium (DU) is a dense toxic and radioactive heavy metal used primarily in military applications. It is mildly radioactive, with about 60% of the activity of natural uranium also containing at least three
times less $^{235}$U than the natural uranium, and contains about 99.8% $^{238}$U, 0.2% $^{235}$U and 0.001% $^{234}$U by mass (WHO, 2003).

Total organic carbon (TOC) is the carbon (C) stored in soil organic matter (SOM), which is any compound containing the carbon atom, except CO$_2$, this refers specifically to the organic carbon fraction, which is one of three basic forms of total carbon; inorganic (carbonates and bicarbonates) organic, and elemental carbon, this means that TOC is the sum of inorganic carbon plus organic carbon. Soils represent the largest terrestrial stock of C, holding approximately 1,500 gigatons (1015 gigatons) C in the top metre. This is approximately twice the amount held in the atmosphere and three times the amount held in terrestrial vegetation (Lal Rattan 2008; Milne and Heimsath 2012). Soil organic carbon is important for the function of ecosystems and agro-ecosystems having a major influence on the physical structure of the soil, the soil’s ability to store water (water holding capacity), and the soil’s ability to form complexes with metal ions and supply nutrients. Loss of SOC can, therefore, lead to a reduction in soil fertility, land degradation and even desertification, which in turn influence water relations, aeration and workability (Pluske et al. 2007). Without forgetting that the soil carbon is a major constituent of soil colloids which play a role in maintaining soil structure as well as adsorbing nutrients. As such, loss of soil carbon is a good indicator of soil degradation. Total organic carbon influences many soil characteristics including colour, nutrient holding capacity (cation and anion exchange capacity), nutrient turnover and stability, which in turn influence water relations, aeration and workability.

Nitrogen is found in both organic and inorganic forms in soil. Organic forms occur in soil organic matter which consists of three primary parts including small (fresh) plant residues and small living soil organisms, decomposing (active) organic matter, and stable organic matter. Soil organic matter (SOM) is composed of the living (microorganisms), the dead (fresh residues), and the very dead (humus) fractions (Hoorman and Islam 2010). Soil organisms are classified according to their size from < 0.2 mm to > 2 mm in width, these organisms include earthworms, nematodes, protozoa, fungi, bacteria and different arthropods. We know that soil organisms break down organic matter, making nutrients available for uptake by plants and other organisms. Microbial exudates act to maintain soil structure.

Soil respiration (SR) refers to the production of carbon dioxide when soil organisms respire. This includes respiration of plant roots, the rhizosphere, microbes and from simple sugars and carbohydrates to the more complex proteins, fats, waxes, and organic acids. The releases of contaminants into the environment increase the total carbon content present in the soil (Schumacher 2002). In soils naturally-occurring TOC forms are derived from the decomposition of plants animals and microorganisms, a wide variety of organic carbon forms are present and range from freshly deposited litter (e.g., leaves, twigs, branches) to highly decomposed forms such as humus, in addition to the sources that are derived as a result of contamination through anthropogenic activities, Various sites may contain discrete organic carbon bearing particles such as wood fibbers from pulp mill wastes or leather scraps from tannery wastes. Total organic carbon influences many soil characteristics including colour, nutrient holding capacity (cation and anion exchange capacity), nutrient turnover and stability, which in turn influence water relations, aeration and workability.
fauna. Soil respiration is a key ecosystem process that releases carbon from the soil in the form of CO₂. CO₂ is acquired from the atmosphere and converted into organic compounds in the process of photosynthesis. Plant structural components are consumed by heterotrophs. This heterotrophic consumption releases CO₂ and when this CO₂ is released by below-ground organisms, it is considered soil respiration.

Soil respiration rates can be largely affected by human activity and pollution, and the microbial population of the soil are a major influence on the amount of organic matter found in soil. Soil respiration and its rate across ecosystems is extremely important to understand because soil respiration plays a large role in global carbon cycling as well as other nutrient cycles. The respiration of plant structures releases not only CO₂ but also other nutrients in those structures, such as nitrogen (Hoorman and Islam, 2010). Soil respiration is a key ecosystem process that releases carbon from the soil in the form of carbon dioxide.

**Martial and Methods:**

This study will provide information on the behaviour of DU in the environment especially in the soil, and would offer first-hand basis on the impact of DU contamination on the soil health, but in particular, the objective of this environmental study is to determine the influence of different concentration of Uranium on soil total organic carbon (TOC), soil total nitrogen (TN), and soil microorganisms activity (soil respiration), in sand cultivated with *Acacia albida* and *A. nelotica* seedling of three months.

In order to investigate the effects of Uranium on the TOC, TN and microorganisms activity in the soil of Acacia species, research designed with two species of Acacia, five treatments (five concentrations of uranium as Uranyl nitrate solutions (UO₂(NO₃)₂)), and four replication of each treatment. In sandy soils, two species of Acacia seedlings (*Acacia albida* and *A. nelotica*) cultivated in individual plastic pots (12 cm diameter) were filled with 500 g of dry sand, pots placed in growth chamber, the growth cabinet experiment supplemented with a 16 h light and 8h dark, 25-30°C day-night regime with 70% humidity. Three-months old seedlings (plants approx. 10 cm high) were exposed to different concentrations of Uranium as Uranyl nitrate solutions (UO₂(NO₃)₂), (0.0,50,100,200, and 500 mg kg⁻¹ soil), these solution prepared form a stock solution of 20g⁻¹ of UO₂(NO₃)₂, with ½ strength of Hoagland solution used as nutrient solution.

**Organic Carbon (TOC) –** material derived from decaying vegetation, bacterial growth, and metabolic activities of living organisms or chemicals. TOC and TN in soil solution was determined with a Shimadzu TOCV-TNM1 analyzer (Shimadzu Corp., Kyoto, Japan). The TOCV-TNM1 analyzer injects 50 ml of soil solution or extract into a combustion furnace held at 720°C with subsequent detection of N₂O using a hemiluminescence detector. KNO₃ or Na-EDTA was used as a standard.

**Microbial activities measured by soil respiration using soil respiratory laboratories analyser.** Soil respiration was measured with a closed dynamic system (IRGA: CIRAS-1, soil chamber: SRC-1, PP-Systems, Hitching, U.K.).

SOM contains approximately 58% C; therefore, a factor of 1.72 can be used to convert OC to SOM (Edwards et al., 1999). TOC is expressed as percent C per 100 g of soil. The following equation is used to estimate the total organic matter content of soil from OC measurements: % Organic Matter = % Organic Carbon x 1.78

Statistical analysis (SPSS) used, and Greenhouse (repeated measures), any results were considered significant at the p < 0.05 level. Pearson Product Moment Correlation used to study the correlation of uranium
content between soil continents of TOC,TN and SR and uranium treatments.

Results:

The treatment with different conc. of uranium highly significant \( p<0.001 \) affected total organic carbon in the soil of \( A.albida \), whereas there is no effect of uranium on \( A.nilotica \). the interaction between the two species is highly significant \( p<0.001 \) with uranium treatment (figure 1).

Total organic matter in the control samples of \( Acacia \ albida \) is about 21\%, but for \( A. \ Nilotica \) about 15\%, while for the treatment with uranium, TOM decrease gradually by increasing uranium concentration in the soil in both species, but in \( Acacia \ albida \) too clear than \( A. \ Nilotica \), about 13\%, and about 14.5\% in 500mgkg\(^{-1}\) treatment respectively.

Figure 1: Total organic carbon in different treatments with uranium (mg.L\(^{-1}\))

The total organic nitrogen decreased highly significantly \( p<0.001 \) in \( A.nilotica \) and significantly \( p<0.05 \) in \( A.albida \) with the increasing of uranium conc. (figure 2).

Figure 2 : Total organic nitrogen in different treatments with uranium (mg.L\(^{-1}\))

TOC and TN was higher in soil planted with \( A.albida \) than that in soil \( A.nilotica \) significantly, but \( A.nilotica \) more affected with uranium pollution of TN quantity in soil than \( A.albida \).

Microbial soil activities affected negatively highly significant \( p<0.001 \) with uranium treatment specially at 200 and 500 mg.kg\(^{-1}\) in the soil of the two species. the soil respiration which reflects the microbial activity, in case of \( A.albida \) in the treatment of 50-100 mg.kg\(^{-1}\) uranium in the soil was found to be almost as the control and in \( A.nilotica \) all the uranium conc. were found to have effect on the soil respiration compared with the control (figure 3).

Figure 3 : Soil respiration for \( A.albida \) and \( A.nilotica \) (mmole.hour\(^{-1}\))
The relation between different concentrations of uranium and two species of Acacia, and the impact of these treatments on soil content of TOC, TDN and soil microorganisms activities, we found there is a relationship between the treatments and Acacia species (Fig. 4 ad 5), but the correlation with *Acacia Nilotica* was positive and more stronger than *A. albida*. It also found the impact of the relationship between the treatments and the amount of TOC is a strong positive relationship, but *A. albida* more affected with uranium treatment than *A. nilotica* especially in high concentrations of uranium (500 mg kg⁻¹) (Fig. 6 and 7).

There is also a negative correlation between soil respiration and the amount of TOC for *A. albida* and absence this relationship in case of *A. nilotica* for the relationship effect soil contamination with uranium in Acacia culture (Fig. 8 and 9).

Figure 4: The correlation between the treatments (U conc. mgkg⁻¹) and TOC, TN, and SR. for *A. albida*.

Figure 5: The correlation between the treatments (U conc. mgkg⁻¹) and TOC, TN, and SR. for *A. nilotica*.

Figure 6: The correlation between the treatments (U conc. mgkg⁻¹) and TOC for *A. albida*.
Discussion:

In general, soil contamination of Uranium is considered a direct impact on the content of soil organic matter, soil organic carbon and all come as a result of soil organisms affected by soil contaminated with uranium. Microbial soil activities are highly affected with uranium treatment specially with high level of uranium contamination (over 200 mgkg⁻¹) in the soil of the two species of Acacia, these due to the uranium toxicity, this is consistent with the study stated by Shepparda, et al., 2005 that the uranium (U) can be greater risk from chemical toxicity than radiological toxicity (depending on the isotopic composition). (Shepparda, et al. 2005). Also, when SOC decrease in the soil due to the pollution with uranium concentration, microorganisms quantity and its activities decreased, because SOC is the main source of energy for soil microorganisms (Gallardo & Schlesinger 1995; Hogberg & Ekblad 1996). Our results also agree with the results obtained by Gongalsky (2003), that the contamination caused by uranium has severe negative biological effects on important groups of the soil food web. (Gongalsky 2003). TDN showed significant decreased as
the concentration of uranium tailing increased indicating a drop of OM decompose as well as decreased amount and activity of soil organisms.

One of the important factors that affected the rate of organic matter decomposition is the microbial population of the soil, and this considered the major influence on the amount of organic matter found in soil. These support the viewpoint that Uranium pollution has the high potential to kill and Inhibition microorganisms activity by toxic and radioactive effects, and this is consistent with the results that we have obtained about the low amount of nitrogen in the soil with increasing uranium concentration pollution. Taking into the consideration that organic residues that have a low nitrogen content can cause nitrogen deficiencies in plants as microorganisms decompose the organic compounds. While organic carbon is added to soil, the rate of soil respiration increases. In TCA cycle, Plants, fungi, animals and bacteria all use this cycle to convert organic compounds to energy, this is an important step in cellular respiration. In the TCA cycle, a six carbon sugar will be oxidized. This oxidation produces the CO₂ and H₂O from the sugar, the second stage of cellular respiration, the three-stage process by which living cells break down organic fuel molecules in the presence of oxygen to harvest the energy they need to grow and divide. This metabolic process occurs in most plants, animals, fungi, and many bacteria. (Berg et al. 2002).

Total nitrogen (TN) is a measure of both inorganic and organic forms of nitrogen and is expressed as a percentage, while inorganic N represents only 2 to 5% of the total nitrogen in the soil (Cathcart 2010), but in our results the TDN increased with uranium treatment augmentation, this due to the present of nitrite ion in the solution used with application (Uranyl nitrate solutions (UO₂(NO₃)₂) in the treatments, for this reason also we did not found any relationship between soil nitrogen content and treatments.

Soil respiration is a key ecosystem process that releases carbon from the soil in the form of carbon dioxide. As the carbon cycle, and soil respiration, have a high relationship to climate change (Luo & Zhou 2006).

**Abbreviations:**

- U Uranium
- DU Depleted Uranium
- SOM Soil Organic Matter
- TOC Total Organic Carbon
- TDN Total Dissolve Nitrogen
- TN Total Nitrogen
- SOC Soil Organic Carbon
- SR Soil Respiration

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