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Trace elements assessment in agricultural and desert soils of Aswan area, south Egypt: Geochemical characteristics and environmental impacts

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Determination of chemical elements, Al, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, P, Pb, Sc, Sr, Ti, Y, and Zn have been performed in agricultural and desert soils and alfalfa (*Medicago sativa*) at Aswan area. Consequently, the pollution indices, univariate and multivariate statistical methods have been applied, in order to assess the geochemical characteristics of these elements and their impact on soil environmental quality and plant, and to reach for their potential input sources. The investigation revealed that the mean and range values of all element concentrations in agricultural soil are higher than those in desert soil. Furthermore, the agricultural soil displayed various degrees of enrichment and pollution of Cd, Zn, Mo, Co, P, Ti, Pb. The geochemical pattern of integrated pollution indices gave a clear image of extreme and strong pollution in the agricultural soil stations, their poor quality with high risk to human health and considered as a tocsin for an alert. In contrast, the desert soil is the good environmental quality and safe for plant, animal and human health. Alfalfa is tolerant plant and considered as a biomarker for P and Mo in polluted agricultural soil. Four geochemical associations of analyzing elements in agricultural soil and three ones in desert soil have been generated, and their enhancements were essentially caused by various anthropogenic activities and geogenic sources. The investigation also revealed that the broad extended desert soil is fruitful and promising as cultivable lands for agricultural processes in the futures.

1. Introduction

Historically, the most of the pristine agricultural soil in Aswan was formed during the flood periods since Pharaonic times until the erection of two Aswan Dams; Old (1898–1902) and High Dams (1960–1976). Where, the Nile River flooded every year and deposited sediments (fine sand, silt and clay) on the both sides of the River Nile in Upper Egypt forming narrow strips of fields. It was creating annually fertile soil, protecting and supporting farmland to produce bountiful crops.

Due to a lack of Nile sediment deposition and natural soil fertility after construction both Dams, all farmers have been compelled to use chemical and organic fertilizers, fungicides and pesticides to grow and protect their crops. Consequently, extensive use of these materials had been devastating effects on agricultural pristine soil because they could be a major contamination source and responsible for the distribution of heavy metals in the mentioned soil (Chun et al., 2011; Ağca and Őzdel, 2014). As well as, they may usually contain a wide variety of heavy metals as impurities (Nicholson et al., 2003), and specific pesticides cause potential threats to environmental and agricultural systems closely related to human health (Chun et al., 2011). On the other hand, there are other anthropogenic sources could contribute trace elements in the environment, causing great changes over a long period of time and resulted in a pollution of soil and water resources. For examples, the natural population increase, unplanned urbanization construction, rural and urban sewage, waste disposal, atmospheric dust, traffic emissions, industry emissions and effluents, and local mining and quarry activities.

Heavy metals are also found in only trace amounts in water, and most of them are initially adsorbed by the suspended particles in water (Che et al., 2003). They could be soluble, transported by water, dispersed to, and deposited in agricultural soil (Qi et al., 2011), resulting in eventual accumulation to elevated levels in the

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soil. With intensive cultivation or agricultural activities, trace elements will be enriched, dangerous, and caused an increasingly serious problem (Wong et al., 2002) because of their persistence and toxicity in the biological system; they are not biodegradable and can be accumulated leaving their fingerprints in sediments and environment over time (Adriano, 2001; N'guessan et al., 2009). Nevertheless, their excessive accumulation may result in environmental contamination, elevate trace elements uptake by crops and subsequently influence public health via food production (Muchuweti et al., 2006). In the sense that they can be accumulated in plants and animals, and then pass through the food chain and living organisms to human beings as the final consumer (Cui et al., 2004).

On the other hand, the desert soil is different in the provenance because it was originally derived from weathering processes acting on the country rocks of the area and its environs. Accordingly, the trace elements in soil can be derived from geogenic and anthropogenic sources, thus, the soil compartment is receiving every year a significant amount of pollutants from different sources (Franco-Uría et al., 2009).

Due to enforcement of environmental regulations is less stringent in developing countries; heavy metals enter the food chain through agricultural production (Dileepa Chathuranga et al., 2013). Franco et al. (2007) found that, some grass and plants have a potential to bioaccumulate high levels of metals from soil, and their high levels may have negative effects on plant and may create serious problems with respect to their suitability as food for animal (Franco et al., 2007). Thus, the authors used alfalfa (*Medicago sativa*) in this study because it is the common famous foods and forage for livestock, cattle, camels, sheep, goats, rabbits and poultry that are being the main source for meats in the Aswan area.

According to the authors' knowledge, no study has previously performed comprehensive investigations during the past decades in Aswan area to assess geochemical characteristics of trace elements and their impact on the agricultural and desert soils. Thus, there is a real need to achieve the geochemical investigation of some element concentrations in both soils and alfalfa (*Medicago sativa*) to reveal their geochemical differences, associations and fingerprint in the soil's quality, to assess the spatial distribution of their anomalous locations, bioaccumulation levels, potential environmental risk and identify possible pollution sources.

2. Description of the study area

The present study was carried out in the area between Aswan and Sharawna, which is located in the southern part of Egypt (Fig. 1). It extends nearly for 159 km long over an approximate latitudinal range of 23°54′–25°18′N and longitudinal range of 32°24′–33°18′E.

The agricultural soil (black color) forms two narrow strips on the both sides of the River Nile, is considered as principal regions of agricultural production in the study area. It was mainly derived from recent sediments deposited by River Nile before construction of the two Aswan Dams and bounded by desert and related soils. Alfalfa (*Medicago sativa*) is growing in the agricultural soil and being the essential food for the domestic and livestock animals (e.g. camels, cattle, goats, sheep, rabbits, poultry, geese and ducks). On the other hand, the desert soil (yellow color) under investigation is wide and extends in the Western Desert away from the River Nile course. It is usually without land use, rare annual rainfalls, a very scanty shrub, distributed in the hilly regions and commonly originated as a result of weathering processes acting on the country rock of the study area and their environs. Geologically, the country rocks of the area consist of the igneous and metamorphic rocks of Precambrian age (mainly schist and gneisses, granitoids, metavolcanics), exposed in the Eastern side of River Nile and overlain northward by the Paleozoic and Cretaceous sedimentary succession that is represented by sandstones, shale, clay stone, phosphate and lime stones. On the Western side of the Nile River, the mentioned sedimentary succession has been exposed and all succession has been capped by the Quaternary deposits, including gravel, sand sheets and alluvium deposits (CONOCO and EGPC, 1987).

The climate of the entire study area is in general described as a subtropical zone with an arid and hot desert climate and it has the hottest summer days of any other city in Egypt. The annual average temperature ranges from 30 °C to 45 °C in summer, which is long and hot, and 15–25 °C in winter, which is short and cold. During the all year, the area has a great amount of solar radiation and few monsoons.

The study area includes some industrial activities, such as factories of fertilizer and cement, abandoned iron ore mines, and clay, shale and sand- and limestone quarries at Aswan, factories of sugar and complementary industries, plant oils and soap, and dairy milk at Kom Ombo, factories of sugar and integrated industries, ferrosilicon, and pulp and paper making at Idfu, and phosphate mining and their concentration factory at Sebeyia. It includes also cultivation activities and scattered urbanization, significant density of vehicles and population, traffic ways and locomotive railways passing beside and near the River Nile and soils.

3. Material and methods

3.1. Sample collections and preparations

Agricultural and desert soils and shoot of alfalfa (*Medicago sativa*) had been sampled in one occasion (August 2011) from the selected station as seen in Fig. 1 in order to achieve the main objectives of the present study.

3.1.1. Soil samples

Total 44 samples of agricultural soil and 22 samples of desert soil were selected from 33 sampling stations covering the study area. At each sampling station, the soil sample was collected from four different sites over an area nearly 25 m^2 at a surface horizon (top 4 cm) and subsurface horizon (30–45 cm depth) depending on the topography situation and alfalfa (*Medicago sativa*) fields. About 10 kg of soil material was taken at each sampling station using shovel, mattock and plastic trowel. They were sealed in clean labeled polyethylene bags, kept in an isolated ice box and transported to the laboratories in the same day. In the laboratory, the soil samples were air dried at room temperature (ca. 35 °C) for a few days, crushed softly for disintegrating. Consequently, stones and plant fragments were removed by screening the friable sample through the minus one mm stainless steel sieve. The obtained soil samples were quartered to 50 g and ground using electromechanical agate mortar to pass finally through 63 μm sieve for chemical analytical purpose.

3.1.2. Plant samples

Twenty-two samples of shoot of alfalfa (*Medicago sativa*) were selected from 22 sampling stations covering the study area. At each sampling station, the plant sample was collected from four different sites over an area (ca. 25 m^2) from the same sampled agricultural soil sites at the same time. About 10 kg of alfalfa shoot was collected at each sampling station by sickle, washed immediately thoroughly with fresh water and followed by Milli-Q water in the field to remove soil and dust particles, stored in numbered clean brown bags and placed in the isolated ice box before sending