Assessment of metallic trace element contents of soils and plants of urban and suburban areas of Safi City (Morocco)

Btissam MANDRI
Laboratoire Interdisciplinaire de Recherche en Bioressources, Environnement et Matériaux «LIRBEM», Cadi Ayyad University, Trainee Teachers Institute,
Hicham EL KHALIL
h.elkhalil@uca.ac.ma
Laboratoire Interdisciplinaire de Recherche en Bioressources, Environnement et Matériaux «LIRBEM», Cadi Ayyad University, Trainee Teachers Institute,
Ali BOULARBAH
Laboratoire de Bioressources et Sécurité Sanitaire des aliments, Cadi Ayyad University, Faculté des Sciences et Techniques,

---

Article

Keywords: Metallic trace elements, Soil and plant contamination, Bioaccumulation Factor, Contamination Factor, Pollution Load Index, Urban and Suburban Areas

Posted Date: September 4th, 2024

DOI: https://doi.org/10.21203/rs.3.rs-4823501/v1

Additional Declarations: No competing interests reported.

Version of Record: A version of this preprint was published at Scientific Reports on October 31st, 2025. See the published version at https://doi.org/10.1038/s41598-024-81184-6.

Assessment of metallic trace element contents of soils and plants of urban and suburban areas of Safi City (Morocco)

Btissam MANDRI[1], Hicham EL KHALIL[1*], Ali BOULARBAH[2]

[1] Laboratoire Interdisciplinaire de Recherche en Bioressources, Environnement et Matériaux «LIRBEM», Cadi Ayyad University, Trainee Teachers Institute, Marrakech, Morocco
[2] Laboratoire de Bioressources et Sécurité Sanitaire des aliments, Cadi Ayyad University, Faculty of Sciences and Techniques, Marrakech, Morocco

*corresponding author: H. El khalil

E-mail address: h.elkhalil@uca.ac.ma
Phone: (+212) 6 62 29 93 28
Fax : (+212) 5 24 34 22 87

MANDRI Btissam : btissam.mandri@uca.ac.ma

BOULARBAH Ali: a.boularbah@uca.ac.ma

Abstract

Our paper syntheses results obtained from studying the effect of typical contamination sources on soils and plants in selected urban and suburban areas in the Safi City. Using common methods, the physicochemical characterization and metallic trace elements (TEs) contents of plants and soils, collected from different urban areas, control area (CA), cement factory (SF), uncontrolled landfill (UL), treatment and transformation unit of phosphate (TP), were determined. Results show that the studied urban and suburban areas can be qualified as polluted by metallic trace elements and the most polluted one is TP area (CA < SF < UL < TP). Results underline the significant contribution of the atmospheric pollution on the contamination of soils and plants collected from TP, UL and surrounding areas with TEs. The most contaminated plants species by TEs are those sampled from TP area and they are *Eucalyptus globulus*, *Nerium oleander*, *Ficus carica* and *Medicago sativa*. *Sinapis arvensis L.* and *Carpobrotus edulis* plants come in the second level with remarkable contamination levels of TEs respectively. Industrial activities in urban areas constitute a potential source of contamination of soils and plants by metallic trace elements that may pose real health risk for human population in the city. We can considered this study as a primary work to develop a global process to assess the environmental contamination of plants and soils in the region of Safi city. It can help us to manage potential polluted sites in a sustainable development strategy.

Keywords: Metallic trace elements; Soil and plant contamination; Bioaccumulation Factor; Contamination Factor; Pollution Load Index; Urban and Suburban Areas.

Acknowledgments: The authors acknowledge Mr. Hassan LAMTAAI and Mr. Yassine Oualcadi (technical staff in Trainee Teachers Institute of Marrakech) for their valuable technical assistance.

Introduction

By 2050, the population of the world is projected to exceed 9.5 billion. According to FAO (2015), more than 50% of this population lives in cities and urban areas (54% in 2014), and by 2050, it will increase to reach more than 66 % (FAO, 2015). The demographic explosion is generally accompanied by the evolution and the intensification of human activities, whether industrial, agricultural or urban activities. This can dramatically affect the urban environment by the release of different organic and/or metallic pollutants, which contribute to air, water and soil contamination. Urban activities are responsible of air pollution (Norra and Stüben 2004; Jin *et al.* 2016; Xian *et al.* 2020; Zgłobicki *et al.* 2018), water contamination (El Khalil *et al.* 2008a; Abdalla and Khalil, 2018), soil contamination mainly by toxic metallic trace elements (Wong et al. 2006; El Khalil et al. 2008b; Wei and Yang 2010; El Khalil et al. 2013; El Khalil et al. 2016; Naylo et al. 2019; Laaouidi et al. 2020), soil degradation by consumption, desertification, and sealing (Scalenghe and Marsan 2009; Salvati et al. 2014; Charzyński et al. 2019) and for global and local climate change (Darmanto et al. 2019). In order to meet the growing demand for crops production, urban agriculture is a favorable and promising solution. Urban agriculture can help also to reducing greenhouse gas emissions at urban area. However, the use of increasingly contaminated soils can constitute a high risk for livestock's animals and for human's health. In urban environment, the soil contamination by metallic trace elements constitutes a serious health risk to the population (Jolly et al. 2013; Khan et al. 2015; Laaouidi et al. 2020). Urban soils contamination constitutes the key way of metallic pollutants transfer to human by food chain (Wong et al. 2006; Laaouidi et al. 2020). The main origin of metallic trace elements in urban soil is anthropic resources. Anthropic metallic contamination of soil in urban areas can originate from air pollution, industrial activities and agricultural practices. Air pollution can be generated by direct releases from industrial activities on the soils or, indirectly, by air fallout after the dispersion of metallic trace element in the atmosphere (Baize 1997; Kabata-Pendias and Pendias 2001). In anthropized soils, both lithogenic and pedogenic metallic trace elements will be less mobile and less bioavailable than anthropogenic elements (Kabata-Pendias and Pendias 2001). Plants, like other organisms, provide different mechanisms to resist to abnormal concentrations and/or high metallic trace elements concentrations stress. Growing plants on contaminated soil localized in urban and suburban areas can potentially lead to the accumulation of metallic trace elements constituting a risk to animals and to human health (Kabata-Pendias and Pendias 2001; Kabata-Pendias 2004; Li et al. 2014; El Hamiani et al. 2015; Laaouidi et al. 2020). The metallic trace elements uptake or accumulation by plants can have a several aspects of the hazards. According to phytotoxicity, it causes the vegetation cover loss, it introduces metallic trace elements into the food chain and it contributes to the cycling of these metallic trace elements to topsoil, leading to toxic effects on both flora and fauna (McLaughlin 2001; Moreno-Jiménez et al. 2010; Chen et al. 2016; Liang et al. 2017; Sun et al. 2018). Despite the reported diversity in the toxicity levels, it can be stated that Cd, Cu, Cr, Hg, Ni, Pb and Zn are the toxic metallic trace elements for both higher plants and some microorganisms (Kabata-Pendias and Pendias 2001, Kaur and Garg 2021; Ali et al. 2023). The elements Cd, Cu, Cr, Pb are considered highly phytotoxic due to their high solubility in water and their easy uptake by plants. Even at low concentrations, plants can uptake metallic trace elements which is the main way of its transfer to the food chain (Kabata-Pendias and Pendias 2001; DalCorso et al. 2010, Li et al. 2014; Tiwari and Lata 2018; Wang et al. 2020). In the city of Safi, the population exceed 691 983 habitants, is one of the industrial centers of the Marrakech-Safi region located in the center of Morocco (DRMS 2017). In this city, urban and suburban agricultural activity is characterized by practices intended for common crops (cereals, legumes, vegetable crops and fodder crops). In Safi province, trees production is dominated mainly by olive, vine, and fig. The processing industries of the province of Safi are dominated by chemical industries, agro and food industries and the metallurgical industries. This region is known by the industrial units for the treatment of phosphate (phosphoric acid and fertilizers), located in the city of Safi with a production mainly intended for export, and quarries of minerals extraction. These minerals are exploited for the pharmaceutical industry, earthenware industry, construction sector and in the cement factories distributed throughout the region (DRMS 2017). According to the metallic trace elements composition of Moroccan phosphate ores presented by Silva et al. (2010), the use of these materials in the phosphoric acid and fertilizers production may have serious environmental impacts, because they are potentially contaminated by metallic elements (Silva et al. 2010). The cement factories constitute a potential metallic trace elements pollution origin. Due to the deposition of cement dust in the surrounding of these cement factories, the soil physic-chemical proprieties may be affected and the accumulation of metallic trace elements may be hazardous to the soil, plants, animals and human health (Al-khashman and Shawabkeh 2006; Zerrouqi et al. 2008; Khamparia et al. 2012; Uzma et al. 2018, Blois and Lay-Ekuakille 2021). Urban and industrial waste are generated all over the time. They are dumped without any treatment in non-controlled landfill. In the Safi City, there is many landfill sites constituting a potential risk because they contribute to the soil contamination manly by metallic trace elements that may be also hazardous to the soil, plants, animals and human health (Meneses et al. 1999; Hakkou et al. 2001; Segura-Muňoz et al. 2004; El Maguiri et al. 2017; de Cassia Silva Bacha et al. 2021; Benhamdoun et al. 2023). Several works confirmed the coastal contamination by different metallic trace elements in the region of Safi (El Makhfouk et al. 2003; Ait Fdil et al. 2006; Benbrahim et al. 2006; Maanan 2007; Erramli et al. 2008; Boundir et al. 2019). However, there is no published data or research works studied the contamination of soils and/or plants by metallic trace elements in the city of Safi.

Therefore, our study aimed at assessing of metallic trace elements contamination, mainly Cd, Cr, Cu, Pb and Zn, in soils and in some common plants species located around the main potential polluted urban and suburban areas in the Safi city, in order to describe the pollution level in these different urban areas. This study could improve understanding of the distribution of potentially toxic metallic elements, manly, between soils and plants. These metallic pollutants can be mobilized and, finally, have a serious impacts on the environment and have a serious human health hazard. Our study can be, also, an initiation and a contribution to understand the dynamics of metallic trace elements between urban soils and plants under contrasted land uses conditions.

Material and Methods

Sites description

The studied areas are located in the vicinity of cement factory (SF),, near an uncontrolled landfill (UL) in a suburban area of Safi city and TP, in the vicinity of treatment and transformation unit of phosphate (TP), situated in the city of Safi (Fig. 1) are selected to assess the impact of their potential contamination sources on the soils and plants. Not influenced area was selected us control area (CA) located at Many disciplinary Faculty of Safi. The climate in this region is semi-arid, hot and dry during the summer (from May to November) and a wet and temperate during the winter (from November to April) with an average rainfall of 300 mm year^{-1} (DRMS 2017).

Plant and Soil Sampling and treatment

The table (1) described the sampling strategy adopted for all studied areas. For plants, an investigation of the studied areas has shown that the sampled species are those that are common between these four areas. To assess the impact of contamination origin in different studied areas, plants were sampled from different points in the wind direction and the species identification was confirmed in the Laboratory. For each plant species, an average sample was constituted of five specimens collected in each studied area. The plants samples were oven-dried for 48 h at 70°C, then crushed separately through a steel grinder and the samples were kept at ambient temperature. Six topsoil (0-15cm) were sampled from each studied area. Soil sampling was achieved according to the distance from the penitential contamination source. Soil (1) is the closest, while Soil (6) is the furthest one in all areas except for control area (CA). All soils samples were also constituted by a composite of 5 subsamples. They were homogenized, air-dried, disaggregated, sieved (2 mm) and the pH, the conductivity, total organic carbon (TOC), total nitrogen (TNK) and organic phosphorus (Polsen) were measured according to the common methods (Laaouidi et al . 2019).

Metallic trace elements analyses

To measure the metallic trace elements concentrations, the plant samples were mineralized according to the common method using acid digestion. A sample of 0.5 g of dry matter was introduced into a mixture of 8 mL HNO_3 and 2 mL H_2O_2 and was heated on a sand bath. After filtration through ash-free filter paper (Prolabo), the solution adjusted in a 25 mL vial with 0.1 M HNO_3. Metallic trace element was extracted from the soil samples using aqua regia digestion, as described in the NF standard (French standards) (X 31-415, ISO 11 466) (NF ISO 11466 1995). The quantity of 1g sample of soil was treated with 15 mL HCl and 5 mL HNO_3 and kept at room temperature for 24 h. It was then heated in a sand bath on a hot plate to 50°C for 5 h, and then refluxed at 130°C for 3 h. The samples were filtered, washed with deionized water, and placed in 50 mL volumetric flasks.

To determine the contribution of atmospheric deposition of metallic trace elements, according to El Hamiani et al. (2015), a quantity (5 g) of leaves (fresh weight) of an average plant sample was washed thoroughly three times with deionized water (50 mL). The deionized water sample from the plant washing was collected and stored at 4°C until chemical analysis.

The metallic trace elements concentrations in plants and in soils samples were analyzed by Atomic Absorption Spectrophotometer (Aurora TRACE AI 3000). Metal concentrations in the plants and in the soils were calculated according to dry weigh and the spatial distribution of measured metallic trace elements in different studied areas, was achieved according to the linear interpolation using ArcGIS software (3.1). The Bioaccumulation Factor for plants (BAF) of metallic trace elements from soil to plant were calculated according to the common methodology (Zheng et al. 2007; Hu et al. 2020; Wieczorek et al. 2023) as following:

$$BAF = \frac{\text{Element concentration in plant}}{\text{Element concentration in soil}}$$

The assessment of soil contamination was also carried out using the Contamination Factor (CF). As described by Hakanson (1980), the CF is a single element index and four classes are recognized (Table 2). The CF equation was used as follows:

$$CF = \frac{Average\ content\ of\ metals}{background\ concentration}$$

Following the unavailability of the background concentration of the region of Safi, we considered the average values of the Control Area (CA), less impacted area by urban or industrial activities, as representative of the background concentration.

The Pollution Load Index (PLI), proposed by Tomlinson et al. (1980), was used us an appropriate tool for comparing the pollution levels between different studied areas. According to Angula (1996), the PLI is able to give an estimate of the metal contamination status and the necessary action that should be taken. A PLI value of <0 indicates that the site is unpolluted, $0 < PLI \leq 1$ indicates baseline levels of pollutant present, $1 < PLI \leq 10$ indicates that the site is polluted, $10 < PLI \leq 100$ indicates that the site is highly polluted and $PLI > 100$ indicates a progressive deterioration of environment and immediate intervention is necessary to alleviate the effect of the pollution (Dung et al. 2013).

$$\text{PLI} = \sqrt[n]{\text{CF1xCF2x} \ldots \text{xCFn}}$$

n: Number of metallic trace elements, for our study n=5

CF: Contamination factor for each metallic trace element

Assessment of phosphatase activity in plants

The phosphatase activity was determinated, using p-nitrophenyl phosphate as a substrate, according to the method described by Asmar and Gissel-Nielsen (1997). Samples of leaves from each plant (100 mg of fresh material) were carefully detached and immediately frozen at -80°C. Each sample was crushed with an extraction mixture constituted by 500 µL of acetate buffer (0.1 M, pH 5) and 5 µL of β-mercapto-ethanol. The ground material was centrifuged at 4°C for 30 min at 13,000g. A volume of 100µL of the extract from each sample were incubated at 37°C for 30 min after the addition of a mixture of 200µL of acetate buffer and 200µL of p-nitrophenyl phosphate (p-NPP). The reaction was stopped by the addition of 1 mL of NaOH (0.5N), and the acid phosphatase activity was measured by spectrophotometer at 410nm using a control constituted by the same mixture, replacing the plant extract with acetate buffer. Acid phosphatase activity is expressed in µmole of Pi released per min per g of fresh leaf material.

Statistical Analysis and Quality Control

Data are analyzed using Statistical software STATISTICA (7.1). The measurements are expressed in terms of average. The data are processed using ANOVA I analysis of variance. Pearson's correlation, with $p<0.05$ as the level of statistical significance, was achieved to study the relationship between metallic trace element contents in soil and in plants. Principal Component Analysis was employed to underline potential parameters conditioning the differences observed between studied urban and suburban areas. The quality control for plant and soils analysis was based on the use of ERM® Certified Reference Materials for trace elements (European Community), samples from inter-laboratory comparisons, internal control samples, and duplicates of the analysis.

Results and Discussion

The results of the agronomic characterization showed that studied topsoils had similar properties (Table 3). However, some topsoils, sampled from UL and TP areas presented high values. The soils of the control area CA have a relatively neutral pH (Table 3). The highest pH values were observed for all soils sampled from the area TP, whose pH varies between 8.1 and 8.8, and for some soils sampled from area SF (8.1-8.2). Bayhan et al. (2002) investigations showed that the pollution in the vicinity of cement factories caused changes in some characteristics of the soil with an increase of their pH and their electrical conductivity which can explain the high pH measured in soils sampled from SF and TP areas. The physicochemical factor can affect the concentration of the soil solution for several types of solutes including metallic trace elements. In the acid pH condition, metallic salts are highly mobilized and this can be explained by the destruction of the retention phase (Pickering 1986; Gorbunov et al. 1992). The global load of the solution of studied soils was evaluated by conductivity. It showed that some soils are characterized by a high soluble salt such as in soil 2 (39.1 mS/cm) in area TP and soil 1 (11.4 mS/cm) in area UL (Table 3). Generally, studied soils of the UL area and those of the TP area presented conductivity values relatively higher than the conductivity values measured in soils of the control area (CA) (Table 3). This particularity can have considerable effect on the bioavailability of metallic pollutants in these soils, which can increase their bioavailability and therefore their transfer to plants. The soil organic matter of soils became an important indicator and tool to assess their sustainability. The particularity of urban and suburban soils that they are highly modified by human activities. The results of TOC, TNK and Polsen showed that soils sampled from UL area exhibited the highest values, mainly in soil 1 (47.5 g.kg^{-1}, 2.3 g.kg^{-1} and 3.9 mg.kg^{-1} respectively) and soil 2 (30.0 g.kg^{-1}, 1.9 g.kg^{-1} and 1.8 mg.kg^{-1} respectively) (Table 3). This can directly be related to their proximity to the landfill and to the contributions of organic matter brought by waste amendments (Noirot-Cosson et al 2016; 2017). For soils (1 and 2) sampled from the TP area, they present, also, high phosphorus values (2.5 and 2.29 mg.kg^{-1} respectively), which can be explained by the contributions due to their proximity to the phosphorus mining transformation and treatment unit. The levels measured in studied soils of CA, SF and TP were similar to those found in urban soils of Marrakech (Morocco) presented by Laaouidi et al (2020), Beroigui et al (2020) and to those found in urban soils of Western Paris (Frensh) presented by Zaouche et al (2017). According to the metallic trace elements analysis, the results showed that the soils sampled from the control area (CA) presented the lowest metallic trace elements level comparing to those sampled from SF, UL and TP areas. The contents did not exceed 0.1 mg Kg^{-1} for Cd, 13.0 mg Kg^{-1} for Cu, 19.1 mg Kg^{-1} for Cr, 0.7 mg Kg^{-1} for Pb and 32.0 mg Kg^{-1} for Zn (Table 4). The metallic trace elements contents of soils, sampled from the area TP, contained relatively the highest concentrations followed by those sampled from UL area (Table 4). Their concentration ranged between <dl and 1.7 mg Kg^{-1} for Cd, 24.4 and 30.9 mg Kg^{-1} for Cu, 54.9 and 102 mg Kg^{-1} for Cr, 1.2 and 4.8 mg Kg^{-1} for Pb and 70.6 and 148.7 mg Kg^{-1} for Zn in TP area and between <dl and 0.5 mg Kg^{-1} for Cd, 13.0 mg Kg^{-1} and 24.4 mg Kg^{-1} for Cu, 12.9 and 78.5 mg Kg^{-1} for Cr, 1.05 and 3.9 mg Kg^{-1} for Pb and 17 and 88.9 mg Kg^{-1} for Zn in UL area (Table 4). The highest concentrations for Cd (1.8 mg Kg^{-1}), Cu (30.9 mg Kg^{-1}), Cr (102 mg Kg^{-1}), Pb (4.8 mg Kg^{-1}) and for Zn (148.7 mg Kg^{-1}) were recorded in the soil (1) sampled from TP area and located near of the industrial site (Table 3). Metallic trace elements contents found in soils sampled from SF area were relatively lower than metallic trace elements contents observed in soils of TP and UL areas. The concentrations of Metallic trace elements in SF area soils ranged between <dl and 0.43 mg Kg^{-1} for Cd, 11.4 mg Kg^{-1} and 13.0 mg Kg^{-1} for Cu, 15.2 and 24.3 mg Kg^{-1} for Cr, 0.3 and 1.8 mg Kg^{-1} for Pb and 21.8 and 49.0 mg Kg^{-1} for Zn (Table 3). Results

showed that soils sampled from the nearest point of the main contamination sources for all studied areas were the most contaminated by metallic trace elements (Table 4). The average concentrations of metallic trace elements, measured in soils from different studied areas, showed that it is possible to classify these areas according to their metallic trace elements contamination levels in the order CA < SF < UL < TP. The remarkable concentrations observed can probably explained by the industrial activities present in these areas. Several work showed that the phosphate fertilizer industry and phosphoric acid industry could release an elevated content of metallic trace elements in the environment (Al-Masri et al. 2004; Gaudry et al. 2006; Aoun et al. 2010; Silva et al. 2010). The cement industry can also causes atmosphere, water and soil contamination by metallic trace elements (Al-khashman and Shawabkeh 2006; Zerrouqi et al. 2008; Jin et al. 2016; Arfala et al. 2018). However, in urban areas it is difficult to conclude that trace elements found in soil originate only from industrial activity. The urban activity can contribute also to the pollution of soils (Laaouidi et al ., 2020; Beroigui et al., 2020). The excessive metallic trace elements accumulation was also confirmed in soils of the vicinity of non-controlled public landfill sites (Meneses et al. 1999; Hakkou et al. 2001; Segura-Muňoz et al. 2004; Pruvot et al. 2006; El Baghdadi et al. 2016; Bacha et al. 2021). The highest metallic trace elements concentrations observed in the studied soils are below the limit values required by the WHO and those required by the European Commission (EC), except for the Cd concentration (1.8 mg Kg^{-1}) and Cr concentration (102 mg Kg^{-1}) measured in the soil (1) sampled from the TP area (Table 4). However, which can be explained by the impact of industrial and urban activity (European Commission 2000; WHO/FAO 2007; Martin and Wendy 2009; Yuswir et al. 2015). Compared to metallic trace elements contents in anthropized and urban soils, measured concentrations were relatively similar to metallic trace elements levels found by Laaouidi et al. (2020) in garden soils of urban areas in Marrakech city, they are very low than those found by El Khalil et al. (2008a) in Marrakech urban and suburban topsoils and they are also very low than concentrations measured by El Hamiani et al. (2015) in garden soils sampled from some mining areas located in the region of Marrakech and Ouarzazate cities. The metallic trace elements found in the studied urban and suburban soils can be easily transferred to plants. The knowledge of the metallic contamination of plants in urban areas as well as the impact of the consumption of vegetables cultivated on polluted urban soils on animal and human health remains very limited. The hazard related to the contamination of the food chain by metallic trace elements, were confirmed and their ingestion by human and animals can cause negative health effects (neurological, reproductive, immune, carcinogenic …) (WHO/FAO 2001; Boularbah et al. 2006; Martin and Wendy 2009; Yuswir et al. 2015; Green and Planchart 2018). The metallic trace element concentrations measured in plants sampled from different studied areas are presented in the table (5). The plants sampled from the control area (CA) exhibited, as found for soils, the lowest contents (Table 5). However, the plants, sampled from the TP area, were the most contaminated. They contained relatively the highest contents of Cd (<dl - 0.4 mg Kg^{-1}), Cu (0.864 - 1.826 mg Kg^{-1}), Cr (0.8 – 2.0 mg Kg^{-1}), Pb (0.8 - 1.7 mg Kg^{-1}) and of Zn (4.1 - 19.9 mg Kg^{-1}). The measured metallic trace elements concentrations in different plants were in decrease order: TP > SF > UL. The concentration of these metallic trace elements in studied plants ranged between <dl and 0.2 mg kg^{-1} for Cd, 0.588 and 1.228 mg Kg^{-1} for Cu, 0.66 and 1.6 mg kg^{-1} for Cr, 0.4 and 0.9 mg Kg^{-1} for Pb, 2.6 and 9.5 mg kg^{-1} for Zn in SF area and between <dl and 0.1 mg kg^{-1} for Cd, 0.53 and 0.718 mg Kg^{-1} for Cu, 0.6 and 1.2 mg kg^{-1} for Cr, 0.28 and 0.7 mg Kg^{-1} for Pb, 1.6 and 6.1 mg kg^{-1} for Zn in UL area (Table 5). The metallic trace elements found in studied plants, particularly those collected from industrial area TP, were similar to those reported by Laaouidi et al. (2020) for plants grown in market garden soils irrigated with industrial or domestic wastewater in urban areas

of Marrakech and they were relatively higher than those found in different plants sampled from garden soils of some mining areas of the Marrakech region and of the south of Morocco (El Hamiani et al. 2015). Nerveless, these metallic trace elements concentrations remained very low than metallic contents reported by Boularbah et al. (2006) in different plants sampled from of mining areas in the South Morocco. The metal concentrations in studied plants were below the United States Domestic Animal Metal Toxicity Limits (Kabata-Pendias and Pendias 2001). However, the Cd concentrations of some studied plants exceeded the WHO/FAO limits (0.1 mg Kg^{-1}) mainly for the plants sampled from TP area (WHO/FAO 2001). The results showed different distribution of metallic trace elements contamination of plants depending of the sampling areas. The metallic trace elements concentrations found in all plant species showed that their metallic contamination increases according to the following order: CA < SF < UL < TP and followed the same tend as metallic concentrations of the soils manly in CA and TP areas. However, metallic trace elements contamination levels found in the plants sampled from the SF were higher than those found in plants sampled from the UL in contrast with their distribution according to their soils metallic contamination levels. This result can be related to the atmospheric dust pollution impact known in the vicinity of cement factory (Al-khashman and Shawabkeh 2006; Zerrouqi et al. 2008; Jin et al. 2016; Arfala et al. 2018). Considering the most contaminated area TP, which is characterized by the presence of the Fertilizer production unit, *Sinapis arvensis L.* exhibited the highest concentrations of measured metallic trace elements (Table 5). The same species, *Sinapis arvensis L.* in the SF area, showed also the highest metal contents (Table 5). This area (SF) is characterized by the presence of the industrial unit (Cement Factory). Even if the Cd content measured in *Sinapis arvensis L.* sampled from the TP and SF areas exceeded the WHO/FAO limit, it remained lower than the Cd content reported by Brunetti et al. (2009) in *Sinapis arvensis* (0.71 mg Kg^{-1} of Cd) grown in contaminated soils. The plants of *Sinapis arvensis* were very abundant in the Safi region, which makes them available to livestock (Taleb et al. 1998). This plant can increase the risk of metallic trace elements transfer to the food chain. *Carpobrotus edulis* species sampled from TP area exhibited a relatively high metallic trace elements concentrations. The concentration of Cd (0.3 mg Kg^{-1}) recorded by *Carpobrotus edulis* sampled from TP area exceed also the WHO/FAO limit and can be explained by its ability to accumulate Cd (WHO/FAO 2001; Zhang et al. 2014). The metallic content measured in the *Carpobrotus edulis* sampled from TP area remained very low than the metallic concentrations reported in this plant grown in the sewage sludge used as species for the phytoremediation process (Chiban et al. 2011; Erdogan et al. 2011). In urban environments, plants played an important role by controlling metal pollution. They can immobilize metallic pollutants in the soil via root uptake or by decreasing the air pollution via foliar uptake (Kumar et al. 2008; EL-Khatib et al. 2011; El Hamiani et al. 2015; El-Khatib et al. 2019). The metallic analyses of metallic trace elements contents showed that *Eucalyptus globulus, Nerium oleander* and *Ficus carica* plants, sampled from TP area, exhibited remarkable concentrations (Table 5). The *Nerium oleander* and *Ficus carica*, sampled from the SF area, exhibited also remarkable metallic trace elements concentrations, but they remain lower than those scored by *Sinapis arvensis L.* plants sampled form the same area (Table 5). The *Ficus carica* plants sampled from the UL area presented lower metallic concentrations compared to those observed in the same plants sampled from UL and TP areas. The measured contents of metallic trace elements in *Medicago sativa* plants showed that the plants sampled from TP area were the most contaminated mainly by Cu (0.978 mg Kg^{-1}), Cr (1.0 mg Kg^{-1}), and Pb (0.96 mg Kg^{-1}) (Table 5). *Medicago sativa* plants exhibited relatively the same concentration found in *Eucalyptus globulus* and *Ficus carica* plants sampled from SF area characterized by the presence of the Cement factory (Table 5). The concentrations of Cd found mainly in

Eucalyptus globulus and in *Nerium oleander* plants sampled from TP area exceeded the WHO/FAO limit (WHO/FAO 2001). The *Eucalyptus globulus* plants are known by their high dust holding capacity, which explain their use as green belt surroundings industrial sites such cement industry (Kumar et al. 2008; El-Khatib et al. 2019). This particularity can be explained the relative high concentrations metallic trace elements found in this plant sampled from different studied areas. El-Khatib et al. (2020) showed that *Eucalyptus globulus* can accumulate different metallic trace elements and there metallic levels can be considered as good indicator of metallic trace elements accumulation in urban areas (El khatib et al. 2011; 2020). The plants of *Nerium oleander* showed remarkable concentrations of measured metallic trace elements, except for the *Nerium oleander* plants sampled from the control area CA. These levels were still lower than those reported by Doğanlar and Atmaca (2010) in the same plants in urban areas. The higher contents of these metallic trace elements observed in *Nerium oleander* plants, from TP area, were very low than those reported by Galfati et al. (2011) found in plants of *Nerium oleander* growing near the phosphate treatment industry (Tunisia). Concerning the common fig (*Ficus carica)*, which produce fruits as an edible product, there metallic trace elements contents were lower than those reported in several studies interested by this plant species in urban or industrial areas (Benaissa 2006; El Hamiani et al. 2015; Ugulu et al. 2016; Alzahrani et al. 2017; Reboredo et al. 2018). As a part of the improvement of the forage crops program, *Medicago sativa* plants are introduced to the region of Safi (DRMS 2017). The Alfalfa (*Medicago sativa*) plants, studied in the urban and suburban areas of Safi, are characterized by a similar metallic trace elements contents reported by Rezaeian et al. (2020) in Alfalfa plants selected from industrial and non-industrial areas. However, several studies showed that this plant can accumulate a remarkable concentration of metallic trace elements (Al-Rashdi and Sulaiman 2013; El Hamiani et al. 2015; Mbarki et al. 2018). The variations of the concentrations of metallic trace elements uptake by plants depend on several physicochemical and biological factors which influence their root uptake from the soil and their deposition on the different plants organs (foliage or bark) (Lehndorff and Schwark 2010). In metal stressful urban environment, the plants developed different reactions to the metallic pollution depending on plant species and their physiological characteristics such as its morphology, total leaf surface (Beckett et al. 2000; Freer-Smith et al. 2004; EL-Khatib et al. 2011; Liang et al. 2017; Sun et al. 2018). The Pearson correlation test achieved, presented in the Table (6), showed a strong positive correlation (r = 0.63 to 0.98) between the average concentration of measured metallic trace elements found in the soils sampled from studied areas and the average concentration of these metallic trace elements measured in plants sampled from studied areas ($p<0.05$).

The highest Bioaccumulation Factor for Plants (BAF) values were found for Cd (0.1-0.9), Pb (0.1-1.1) and for Zn (0.03-0.4) (Table 7). This can be related to the higher mobility of Cd, Pb and Zn in soil, and their low retention in the soil than other toxic metallic pollutants (Kabata-Pendias and Pendias 2001). Elevated values of Cd BAF were recorded for *Eucalyptus globulus* sampled from the CA area (0.9), followed by the BAF recorded for *Sinapis arvensis L.* sampled from SF area (0.8) (Table 7). The highest BAF of Pb was also recorded in the plants of Medicago sativa (1.1), *Sinapis arvensis L.* (1.0), *Eucalyptus globulus* (1.0) and *Ficus carica* (0.9) sampled from the SF area. The *Eucalyptus globulus*, sampled from TP area, exhibited also remarkable BAF of Pb (0.8) (Table 7). The BAF values for studied metallic trace elements, for different studied plants, varied greatly between plant species, locations and soil contamination (Table 7). It was apparent that BAF of these metallic trace elements increased with an increase of their concentrations in soils. The BAF for the studied plants were, relatively, similar to those reported by Jolly et al. (2013) and they were very low compared to the BAF values presented by El

Hamiani et al. (2015) for the plants sampled from mining areas us *Ficus carica*. The uptake of metallic trace elements by plant roots was influenced by many parameters controlling their bioavailability such us soil physicochemical properties, plant species and by metallic trace element properties (Song et al., 2016). Thornton and Farogo (1997) considered that a BAF of 0.1 indicates that metallic element is excluding from plant tissues such as 1 out of 6 plants from SF, all from UL, and 5 out of 6 from BAF (Table 7). Chary et al. (2008) suggested that for a BAF above 0.2 indicated an anthropogenic contamination of the plants and for a BAF value higher than 0.5 indicated that plants could be considered as contaminated by metallic trace elements caused by anthropogenic activities, which requires an environmental monitoring of the area (Kloke et al. 1984; Chary et al. 2008). Consequently, the BAF values underlined the impact of anthropogenic activities on the metallic contamination levels of these plants, mainly in the TP and in the SF areas. In these areas, the contribution of atmospheric pollution, with the foliar absorption of atmospheric metal deposits maybe important and is not taken in account by the BAF.

The FC and PLI were used for an environmental assessment of the studied urban and suburban areas. The values of CF were presented in Table (8). As expected, the highest CF values for metallic trace elements analyzed were recorded for TP area. The CF values calculated based on the average metallic trace elements contents showed that soils of SF and UL areas could be classified with moderate contamination (Table 2 and 8). For soils sampled from TP area could be classified with a considerable contamination according to CF values (Table 2 and 8). The CF values calculated based on the metallic trace elements contents showed, also, that the soil (1), the nearest sampling point of the main contamination source for all studied areas, could be classified as a very high-contaminated zone. Concerning the other soils (soil 2 to soil 6), they showed a moderate contamination and a considerable contamination by measured metallic trace elements in different studied areas (SF, UL et TP) (Table 8). The spatial distribution, according to linear interpolation, confirmed that soils, sampled from the nearest point to the contamination sources (soil 1), are the most contaminated mainly for studied areas TP, UL and SF (Figure 3). This spatial distribution showed clearly that the most contaminated soils by metallic trace elements were those sampled from TP area, followed by soils sampled from UL area and followed by soils sampled from SF area (Figure 3). The results confirmed that soils, sampled from nearest sampling points of the potential sources of the contamination in the studied urban and suburban areas were submitted to a huge anthropogenic pressure leading to their contamination. The results confirmed that soils, sampled from different studied urban and suburban areas, near the potential contamination sources, were submitted to a huge anthropogenic pressure leading to their contamination. The assessment of the contamination degree of studied urban and suburban areas of the Safi City using the PLI (Figure 2) indicated that SF, UL and TP areas (13.4, 17.1 and 22.8 respectively) can be qualified us polluted by metallic trace elements ($1 < PLI \leq 10$) (Dung et al. 2013). The most contaminated area TP, located near the industrial area, exhibited the highly PLI (22.8). Consequently, to alleviate the effect of this pollution, it is necessary to take immediate and preventive intervention to avoid a progressive deterioration of the environment quality in these urban and suburban areas. Generally, the negative correlation between the PLI and the BAF could be explained by the toxic effect of metallic trace elements on the plant leading to decreases of their transfer from the roots to the other parts of plant (Ntzala et al. 2012). In our study, a positive correlation between the PLI and the BAF of metallic trace elements was observed (Table 7 and Figure 2). Principal Component Analysis results showed that the characteristics of the TP area stood out and it was much more influenced by parameters related mainly to metallic contents in soils and plants and by some agronomic parameters (pH, Conductivity and P- Olsen) according to the Factor (1) (63%) (Figure 4). For UL area, it was stood out also, however, it was more influenced by agronomic parameters of soils mainly carbon content (TOC), nitrogen content (NTK) and phosphorus content (P-olsen) (Figure 4). Concerning the SF area, it was the only area, which presented relatively close characteristics to those of presented by the control area. Results of Principal component analysis confirmed the similarity between the characteristics of these last two areas (figure 4). The presence of metallic contamination sources contributing to the metallic contamination of soils and plants. According to the characteristics of different studied areas, this contribution to the enrichment of studied soils and plants by metallic trace elements could be related to the contamination by atmospheric deposits. The determination of metallic trace elements levels in the leaves rinsing water of studied plants showed that these levels are very low for the majority of studied areas (Table 9). However, some concentrations measured in the rinsing water of some plants present remarkable levels for some metallic trace elements. *Eucalyptus globulus* and *Ficus carica*, sampled in the SF area, presented remarkable concentrations of Pb (0.15 and 0.09 mg L^{-1} respectively), but they remain lower than those recorded by the same plants sampled in the TP area (0.4 and 0.2 mg L^{-1} respectively). The results of the determination of trace metal elements in the leaves rinsing water also showed that *Eucalyptus globulus* plants, sampled from the TP zone, presented the highest values of Cd (0.08 mg L^{-1}), Cu (0.07 mg L^{-1}), Cr (0.1 mg L^{-1}), Pb (0.4 mg L^{-1}) and Zn (0.9 mg L^{-1}) (Table 9). For *Ficus carica* plants sampled from the TP zone, they presented remarkable values of Cd (0.07 mg L^{-1}), Pb (0.2 mg L^{-1}) and Zn (0.5 mg L^{-1}). The values measured in the leaves rinsing water of these plants underlined the phenomenon of atmospheric deposition of these metallic trace elements in these areas and they are relatively high compared to the total contents found in these plants. The Pb levels observed in the leaves rinsing water of *Eucalyptus globulus* and *Ficus carica*, sampled in the SF area, constituted high percentages (18.5% and 12% respectively) of total Pb concentrations measured in these plants. These percentages are higher for the plants sampled from TP area. They represented for *Eucalyptus globulus* 40% for Cd, 5% for Cu, 5% for Cr, 23.5% for Pb and 4.5% for Zn and for *Ficus carica* 70% for Cd, 23.5% for Pb and 4.5% for Zn. For *Carpobrotus edulis*, sampled in the TP area, the leaves rinsing water presented, also, a remarkable concentration of Zn, which constituted 7.1% of the total concentration of Zn measured in this plants (Table 9). Therefore, it confirmed the impact of the atmospheric pollution underlined by deferent metallic contamination level of metallic trace elements uptake observed in studied plants mainly in *Eucalyptus globulus, Sinapis arvensis L.* and *Carpobrotus edulis*. It was necessary to take into account the number of metallic trace elements used to determinate the PLI and which ones that have the most contribution to the computation of the PLI, such in the case of this study (Angula 1996). The impact of the metallic contamination on plants could be confirmed by the results of phosphatase activity presented in Table 10. Generally, results showed that the leaves phosphatase activity decreases according to metallic trace elements contamination increasing in studied areas. The values observed in leaves of different plants sampled from the TP area (0.3 - 0.9 µmol Pi $min^{-1}g^{-1}$) were the lowest values comparing with phosphatase activity values (0.6 - 2.5 µmol Pi $min^{-1}g^{-1}$) found in leaves of plants sampled from control area (CA). For SF and UL areas, the phosphatase activity measured in leaves of plants (0.6-1.9 µmol Pi $min^{-1}g^{-1}$ and 0.5-1.5 µmol Pi $min^{-1}g^{-1}$ respectively) was relativity low than values of phosphatase activity found in leaves of plants sampled from CA area (Table 10). Plants can be exposed to different types of environmental stress, which can affect their functioning and yield. Metallic trace elements constitute one of the main toxic environmental pollutants and their relative toxicity depends on plant species and on others abiotic conditions (Kabata-Pendias and Pendias 2001, Goswami and Deka 2020). Tejera García et al (2004) underlined the effect of metallic trace element on the phosphatase activity. Metallic trace elements (Cu, Pb and Zn) strongly inhibited the phosphatase activity in leaves and root of

Phaseolus vulgaris (common bean) (Tejera García et al 2004). This can confirm, relatively, our results found for studied plants sampled from urban and suburban areas of the city of Safi. However, the low number of studies and specific data of studied plants could not relate, directly, the decrease of phosphatase activity in leaves of these plants to the metallic contamination.

Conclusion

The metallic contamination of soils and plants in studied urban and suburban areas of Safi City show that the soils receive a non-negligible amount of metallic trace elements. The average contamination levels of measured metallic trace elements in all soils allow to classify these urban and suburban areas in the order CA< SF < UL < TP. The most contaminated soils are those located in urban areas TP and SF respectively. Thus, it constitutes a high hazard related to the transfer of these metallic pollutants to the food chain. The results of metallic trace elements concentrations found in all plants species show that their metallic contamination increases according to the following order CA< UL < SF < TP. This underling the possible accumulative impact of atmospheric dust pollution found in suburban area SF known by the cement factory and in the urban area TP known by the phosphate transformation unit. The most contaminated plants species by metallic trace elements are *Eucalyptus globulus*, *Nerium* oleander, *Ficus carica* and *Medicago sativa*. *Sinapis arvensis L.* and *Carpobrotus edulis* plants come in the second level with remarkable contamination levels of metallic trace elements respectively. This study underlines the impact of anthropogenic activities on the metallic contamination levels of plants mainly in TP and UL areas using the BAF values. The FC and PLI, used to assess the environmental impact, show that studied urban and suburban areas of Safi City, are polluted by metallic trace elements and the most polluted ones were urban areas (TP and UL). The deposit of metallic trace elements on the leaves of plants collected in the vicinity of different contamination sources in studied urban and suburban areas confirm the important impact of the atmospheric pollution and underline also that the soils surrounding different sources of contamination in these studied areas receive considerable amounts of metallic trace. In coordination with local government and deferent industrials actors of the Safi city, these results can be used to propose a global process for an environmental assessment. The acquired knowledge can help to develop new tools used in the decision-making process according to a sustainable development strategy requested by managers.

References

Abdalla F, Khalil R (2018) Potential effects of groundwater and surface water contamination in an urban area, Qus City, Upper Egypt. J Afr Earth Sci 141:164-178. https://doi.org/10.1016/j.jafrearsci.2018.02.016.

Ait Fdil M, Mouabad A, Outzourhit A, Benhra A, Maarouf A, Pihan JC (2006) Valve movement response of the mussel Mytilus galloprovincialis to metals (Cu, Hg, Cd and Zn) and phosphate industry effluents from Moroccan Atlantic coast. Ecotoxicology 15:477–486. https://doi.org/10.1007/s10646-006-0083-3

Ali S, Mir RA, Tyagi A, Manzar N, Kashyap AS, Mushtaq M, Raina A, Park S, Sharma S, Mir ZA, Lone SA, Bhat AA, Baba U, Mahmoudi H, Bae H. (2023) Chromium Toxicity in Plants: Signaling, Mitigation, and Future Perspectives. *Plants (Basel)*. 12(7):1502. https://doi.org/10.3390/plants12071502.

Al-khashman AO, Shawabkeh AR (2006) Metal distribution in soils around the cement factory in southern Jordan. Environ Pollut 140:387-394. https://doi.org/10.1016/j.envpol.2005.08.023

Al-Masri MS, Amin Y, Ibrahim S, Al-Bich F (2004) Distribution of some traces metals in Syrian phosphogypsum. Appl Geochem 19:747–753. https://doi.org/10.1016/j.apgeochem.2003.09.014

Al-Rashdi TT, Sulaiman H (2013) Bioconcentration of heavy metals in Alfalfa (*Medicago sativa*) from farm soils around Sohar industrial area in Oman. APCBEE Proc 5:271-278. https://doi.org/10.1016/j.apcbee.2013.05.047

Alzahrani HR, Kumakli H, Ampiah E, Mehari T, Thornton AJ, Babyak CM, Fakayode SO (2017) Determination of macro, essential trace elements, toxic heavy metal concentrations, crude oil extracts and ash composition from Saudi Arabian fruits and vegetables having medicinal values. Arab J Chem 10:906–913. https://doi.org/10.1016/j.arabjc.2016.09.012

Angula E (1996) The Tomlinson Pollution Index applied to heavy metal, Mussel–Watch data: A useful index to assess coastal pollution. Sci Total Environ 187: 19–56. https://doi.org/10.1016/0048-9697(96)05128-5

Aoun M, El Samrani AG, Lartiges BS, Kazpard V, Saad Z (2010) Releases of phosphate fertilizer industry in the surrounding environment: Investigation on heavy metals and polonium-210 in soil. J Environ Sci 22:1387–1397. https://doi.org/10.1016/S1001-0742(09)60247-3

Arfala Y, Douch J, Assabbane A, Kaaouachi K, Tian H, Hamdani M (2018) Assessment of heavy metals released into the air from the cement kilns co-burning waste: case of Oujda cement manufacturing (northeast Morocco). Sustain Environ Res 28:363-373. https://doi.org/10.1016/j.serj.2018.07.005

Baize D (1997) Teneurs totales en éléments traces métalliques dans les sols (France). Références et stratégies d'interprétation. INRA Ed, France.

Bayhan YK, Yape S, Kocaman B, Nuhoglu A, Cake A (2002) The effects of cement dust on some soil characteristics. Fresenius Environ. Bull. 11:1030-1033.

Beckett KP, Freer-Smith P, Taylor G (2000) Particulate pollution capture by urban trees: effect of species and windspeed. Global Change Biol 6:995–1003. https://doi.org/10.1046/j.1365-2486.2000.00376.x.

Benaissa H (2006) Screening of new sorbent materials for cadmium removal from aqueous solutions. J Hazard Mater 132:189–195. https://doi.org/10.1016/j.jhazmat.2005.07.085

Benbrahim S, Chafik A, Chfiri R, Bouthir FZ, Siefeddine M, Makaoui A (2006) Etude des facteurs influençant la répartition géographique et temporelle de la contamination des côtes atlantiques marocaines par les métaux lourds : cas du mercure, du plomb et du cadmium. . Mar. Life 16:37-47.

Benhamdoun A, Achtak H, Vinti G, Dahbi A (2023) Soil contamination by trace metals and assessment of the risks associated: the dumping site of Safi city (Northwest Morocco). Environ Monit Assess 195: 941. https://doi.org/10.1007/s10661-023-11467-4

Blois L, Lay-Ekuakille A (2022) Environmental impacts from atmospheric emission of heavy metals: A case study of a cement plant. *Measurement: Sensors*, 18: 100313. https://doi.org/10.1016/j.measen.2021.100313

Boularbah A, Schwartz C, Bitton G, Aboudrar W, Ouhammou A, Morel J-L (2006) Heavy metal contamination from mining sites in South Morocco: 2. Assessment of metal accumulation and toxicity in plants. Chemosphere 63:811–817. https://doi.org/10.1016/j.chemosphere.2005.07.076

Boundir Y, Hasni M, Rafik F, Sabri H, Bahammou N, Cheggour M, Achtak H, Cherifi O (2019) First study of the ecological status in the Atlantic coast of Morocco using the brown seaweed *Cystoseira tamariscifolia*. App Ecol Environ Res 17:14315-14331. https//:10.15666/aeer/1706_1431514331

Beroigui M, Naylo A, Walczak M, Hafidi M, Przemyslaw C, Marcin Ś, Szymon R, Boularbah A (2020) Physicochemical and microbial properties of urban park soils of the cities of Marrakech, Morocco and Toruń, Poland: Human health risk assessment of fecal coliforms and trace elements. Catena. 194. https://doi.org/10.1016/j.catena.2020.104673.

Brunetti G, Soler-Rovira P, Farrag K, Senesi N (2009) Tolerance and accumulation of heavy metals by wild plant species grown in contaminated soils in Apulia region, Southern Italy. Plant Soil 318:285–298. https://doi.org/10.1007/s11104-008-9838-3

Chary NS, Kamala CT, Raj D (2008) Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. Ecotoxicol Environ Saf 69:513-24. https://doi.org/10.1016/j.ecoenv.2007.04.013.

Charzyński P, Hulisz P, Piotrowska-Długosz A, Kamiński D, Plak A (2018) Sealing Effects on Properties of Urban Soils [In:] Rattan Lal BA Stewart (Eds.) Urban Soils, CRC Press, Boca Raton – London – New York, 155-174.

Chen P, Miah MR, Aschner M (2016) Metals and neurodegeneration. In: F1000 Research 5. pp. 366. https://doi.org/10.12688/f1000research.7431.1

Chiban M, Soudani A, Sinan F, Persin M (2011) Single, binary and multi-component adsorption of some anions and heavy metals on environmentally friendly *Carpobrotus edulis* plant. Colloids Surf B Biointerfaces 82:267-276. https://doi.org/10.1016/j.colsurfb.2010.09.013

D.R.M.S. (2017) Monographie Générale de la région de Safi. Direction Régionale de Marrakech-Safi, Direction Provinciale de Safi, Haut-Commisariat au Plan Royaume du Maroc Octobre 2017.

DalCorso G, Farinati S, Furini A (2010) Regulatory networks of cadmium stress in plants. Plant Signal Behav 5-6:663-667. https://doi.org/10.4161/psb.5.6.11425

Darmanto NS, Varquez ACG, Kawano N, Kanda M (2019) Future urban climate projection in a tropical megacity based on global climate change and local urbanization scenarios. Urban Clim 29: 100482. https://doi.org/10.1016/j.uclim.2019.100482

de Cassia Silva Bacha D, Santos S, de Alcantara Mendes R. et al. (2021) Evaluation of the contamination of the soil and water of an open dump in the Amazon Region, Brazil. Environ Earth Sci 80, 113 (2021). https://doi.org/10.1007/s12665-021-09401-3

Doğanlar ZB, Atmaca M (2010) Influence of Airborne Pollution on Cd, Zn, Pb, Cu, and Al Accumulation and Physiological Parameters of Plant Leaves in Antakya (Turkey). Water Air Soil Pollut 214:509–524. https://doi.org/10.1007/s11270-010-0442-9

Dung TTT, Cappuyns V, Swennen R, Phung NK (2013) From geochemical background determination to pollution assessment of heavy metals in sediments and soils. Rev Environ Sci Biotechnol 12:335–353. https://doi.org/10.1007/s11157-013-9315-1

EC (European Commission) (2000) Working document on sludge.3rd draft. Env E 80:1–19

WHO/FAO (2007) Joint FAO/WHO Food Standard Programme Codex Alimentarius Commission, 13th Session, Report of the Thirty-Eight Session of the Codex Committee on Food Hygiene, Houston, United States of America, ALINORM 07/30/13

El Baghdadi M, Oumeskou H, Barakat A, Nadem S, Rais J (2015) Effet de la Décharge publique de la ville de Béni-Mellal sur les Sédiments et les Sols au niveau d'Oued Sabeq. J Mater Environ Sci 6 : 3371-3381.

El Hamiani O, El Khalil H, Sirguey C, Ouhammou A, Bitton G, Schwartz C, Boularbah A (2014) Metal concentrations in plants from mining areas in South Morocco: Health risks assessment of consumption of edible and aromatic plants. CLEAN - Soil Air Water 41:1-9. https://doi.org/10.1002/clen.201300318.

El Khalil H, El Hamiani O, Bitton G, Ouazzani N, Boularbah A (2008a) Heavy metal contamination from mining sites in South Morocco: monitoring metal content and toxicity of soil runoff and groundwater. Environ Monit Assess 136:147–160. https://doi.org/10.1007/s10661-007-9671-9

El Khalil H, Schwartz C, El Hamiani O, Sirguey C, Kubiniok J, Boularbah A (2016) How physical alteration of technic materials affects mobility and phytoavailabilty of metals in urban soils? Chemosphere 152:407-414. https://doi.org/10.1016/j.chemosphere.2016.02.116

El Khalil H, Schwartz C, El Hamiani O, Kubiniok J, Morel J-L, Boularbah A (2008b) Contribution of technic materials to the mobile fraction of metals in urban soils in Marrakech (Morocco). J Soils Sediments 8:17–22. https://doi.org/10.1065/jss2008.01.269

El Khalil H, Schwartz C, El Hamiani O, Kubiniok J, Morel J-L, Boularbah A (2013) Distribution of major elements and trace metals as indicators of technosolisation of urban and suburban soils. J Soils Sediments 13:519-530. https://doi.org/10.1007/s11368-012-0594-x

El Maguiri A, Zegzouti Y, Souabi S, Idrissi L, El Hadek M, Rene ER, Pala A, Hafidi M (2017) Landfills: Environmental Impacts, Assessment, and Management in Developing Countries - The Case of Morocco. Chapter in Landfills: environmental impacts, assessment and management. Editor, Norma Chandler, Nova Science Publishers, Inc.,New York.

El Makhfouk M, Souissi A, El Meray M (2003) Analyse de la fraction labile du zinc, cadmium, plomb et du cuivre dissous en milieu marin côtier par la redissolution anodique à impulsions différentielles. C R Chimie 7:689-693. https://doi.org/10.1016/S1631-0748(03)00123-1

EL-Khatib A, El-Rahman A, Elsheikh O (2011) Leaf geometric design of urban trees: potentiality to capture airborne particle pollutants. J Environ Stud 7:49–59.

El-Khatib AA, Barakat NA, Youssef NA, Samir NA (2019) Bioaccumulation of heavy metals air pollutants by urban trees. Int J Phytoremediation 22(2):210-222. https://doi.org/10.1080/15226514.2019.1652883

El-Khatib AA, Youssef NA, Barakat NA, Samir NA (2020) Responses of *Eucalyptus globulus* and *Ficus nitida* to different potential of heavy metal air pollution, Int J Phytoremediation 22(10):986-999. https://doi.org/10.1080/15226514.2020.1719031

Erdogan R, Zaimoglu Z, Budak F, Köseoglu C (2011) Use of sewage sludge in growth media for ornamental plants and its effects on growth and heavy metal accumulation. J Food Agric Environ 9(2):632-635.

Erramli H, Gogon HD, Misdaq MA, Sauvage T, Ramboz C (2008) Study of pollution in the El Jadida-Safi Atlantic coastal zone (Morocco) by using PIXE and SSNTD methods. J Environ Radioact 99:1216-1224. https://doi.org/10.1016/j.jenvrad.2008.02.003

Freer-Smith P, El-Khatib A, Taylor G (2004) Capture of particulate pollution by trees: a comparison of species typical of semi-arid areas (*Ficus nitida* and *Eucalyptus globulus*) with European and North American species. Water Air Soil Pollut, 155:173-187. https://doi.org/10. 1024/B:WATE.0000026521.99552.fd.

Galfati I, Bilal E, BéjiSassi A, Abdallah H, Zaïer A (2011) Accumulation of heavy metals in native plants growing near the phosphate treatment industry, Tunisia. Carpathian J Earth Environ Sci 6:85-100.

Gaudry A, Zeroual S, Gaie-Levrel F, Moskura M, Boujrhal FZ, El Moursli RC, Delmas R (2006) Heavy Metals Pollution of the Atlantic Marine Environment by the Moroccan Phosphate Industry, as Observed through their Bioaccumulation in *Ulva Lactuca*. Water Air Soil Pollut 178:267–285. https://doi.org/10.1007/s11270-006-9196-9

Gorbunov B, Sabelfeld K, Zapadinsky E, Kleitz A, Laali AR (1992) Formation of water aerosol in the steam turbine. Theory and measurements. J Aerosol Sci 24:109-112.

Goswami M, Deka S. 2020. Plant growth-promoting rhizobacteria alleviators of abiotic stresses in soil: A review. Pedosphere. 30: 40–61. https://doi.org/10.1016/S1002-0160(19)60839-8Green AJ, Planchart A (2018) The neurological toxicity of heavy metals: A fish perspective. Comp Biochem Physiol C Toxicol Pharmacol 208:12–19. https://doi.org/10.1016/j.cbpc.2017.11.008

Hakanson L (1980) An ecological risk index for aquatic pollution control, a sedimentological approach. Water Res 14, 975–1001. https://doi.org/10.1016/0043-1354(80)90143-8

Hakkou R, Wahbi M, Bachnou A, Elamri K, Hanchi L, Hibti M (2001) Impact de la décharge publique de Marrakech (Maroc) sur les ressources en eau. Bull Eng Geol Environ 60:325-336.

Hu B, Xue J, Zhou Y, Shao S, Fu Z, Li Y, Chen S, Qi L, Shi Z (2023) Modelling bioaccumulation of heavy metals in soil-crop ecosystems and identifying its controlling factors using machine learning. Environ Pollut 262, 114308. https://doi.org/10.1016/j.envpol.2020.114308

Jin Y, Andersson H, Zhang S (2016) Air pollution control policies in China: a retrospective and prospects. Int J Environ Res Public Health 13:1219−1249. https://doi.org/10.3390/ijerph13121219

Jolly YN, Islam A, Akbar S (2013) Transfer of metals from soil to vegetables and possible health risk assessment. SpringerPlus 2: 385. https://doi.org/10.1186/2193-1801-2-385

Kabata-Pendias A (2004) Soil-plant transfer of trace elements-an environmental issue. Geoderma 122:143-149. https://doi.org/10.1016/j.geoderma.2004.01.004

Kabata-Pendias A, Pendias H (2001) Trace Elements in Soils and Plants. Boca Raton: CRC Press.

Khamparia A, Chatterjee SK, Sharma GD (2012) Assessment on effect of cement dust pollution on soil health. J Environ Res Develop 7:368-374.

Khan A, Khan S, Khan MA, Qamar Z, Waqas M (2015) The uptake and bioaccumulation of heavy metals by food plants, their effects on plants nutrients, and associated health risk: a review. Environ Sci Pollut Res 22:13772–13799. https://doi.org/10.1007/s11356-015-4881-0.

Kloke A, Sauerbeck DR, Vetter H (1984) The Contamination of Plants and Soils with Heavy Metals and the Transport of Metals in Terrestrial Food Chains. In: Nriagu J.O. (eds) Changing Metal Cycles and Human Health. *Dahlem* Workshop Reports, Life Sciences Research Report, vol 28. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-69314-4_7

Kumar SS, Singh NA, Kumar V, Sunisha B, Preeti S, Deepali S, Nath SR (2008) Impact of dust emission on plant vegetation in the vicinity of cement plant. Environ Res Eng Manag 7 (1):31-35. https://doi.org/10.30638/eemj.2008.006

Kaur, H., Garg, N. (2021) Zinc toxicity in plants: a review. *Planta* 253, 129. https://doi.org/10.1007/s00425-021-03642-z

Laaouidi Y, Bahmed A, Naylo A, El Khalil H, Ouvrard S, Schwartz C, Boularbah A (2020) Trace Elements in Soils and Vegetables from Market Gardens of Urban Areas in Marrakech City. Biol Trace Elem Res 195:301–316. https://doi.org/10.1007/s12011-019-01849-6

Lehndorff E, Schwark L (2010) Biomonitoring of air quality in the Cologne conurba-tion using pine needles as a passive sampler. Part III: major and trace elements. Atmos Environ 44(24):2822–2829. https://doi.org/10.1016/j.atmosenv.2010.04.052.

Li Q, Zhou J, Chen B, Huang B, Zeng X, Zhan J, Pan X (2014) Toxic metal contamination and distribution in soils and plants of a typical metallurgical industrial area in southwest of China. Environ Earth Sci 72:2101–2109. doi:10.1007/s12665-014-3118-8

Liang J, Fang H, Zhang T, Wang X, Liu Y (2017) Heavy metal in leaves of twelve plant species from seven different areas in Shanghai, China. Urban For Urban Green, 27, 390–398. https://doi.org/10.1016/j.ufug. 2017.03.006.

Maanan M (2007) Biomonitoring of heavy metals using *Mytilus galloprovincialis* in Safi coastal waters, Morocco. Environ Toxicol 22(5):525-531. https://doi.org/10.1002/tox.20301

Mbarki S, Cerdà A, Zivcak M, Brestic M, Rabhi M, Mezni M, Jedidi N, Abdelly C, Pascual JA (2018) Alfalfa crops amended with MSW compost can compensate the efect of salty water irrigation depending on the soil texture. Process Safet Environ Prot 115:8-16. https://doi.org/10.1016/j.psep.2017.09.001

McLaughlin MJ (2001) Bioavailability of metals to terrestrial plants. In: Allen, H.E. (Ed.), Bioavailability of Metals in Terrestrial Ecosystems. Importance of Partitioning for Bioavailability to Invertebrates, Microbes and Plants. SETAC Press, Pensacola, FL, pp. 39 – 68.

Meneses M, Llobet J, Granero S, Schuhmacher M, Domingo J (1999) Monitoring metals in the vicinity of a municipal waste incinerator: temporal variation in soils and vegetation. Sci Total Environ 226(2-3):157–164. https://doi.org/10.1007/s11783-016-0873-7

Moreno-Jiménez, E., Manzano, R., Esteban, E. et al. The fate of arsenic in soils adjacent to an old mine site (Bustarviejo, Spain): mobility and transfer to native flora. J Soils Sediments 10, 301–312 (2010). https://doi.org/10.1007/s11368-009-0099-4

Naylo A, Pereira SIA, Benidire L, El Khalil H, Castro PML, Ouvrard S, Schwartz C, Boularbah A (2019) Trace and major element contents, microbial communities, and enzymatic activities of urban soils of Marrakech city along an anthropization gradient. J Soils Sediments 19:2153–2165. https://doi.org/10.1007/s11368-018-2221-y

NF ISO 11466 X31-415 (1995) Qualité du sol - Extraction des éléments en traces solubles dans l'eau régalé. AFNOR Editions, Juin 1995.

Noirot-Cosson PE, Vaudour E, Gilliot JM, Gabrielle B, Houot S (2016) Modelling the long-term effect of urban waste compost applications on carbon and nitrogen dynamics in temperate cropland. *Soil Biol. Biochem.* 94, 138–153.

Noirot-Cosson PE, Dhaouadi K, Etiévant V, Vaudour E, Houot S. (2017) Parameterisation of the NCSOIL model to simulate C and N short-term mineralization of exogenous organic matter in different soils. *Soil Biol. Biochem.* 14, 128–140.

Norra S, Stüben D (2004) Trace elements and seasonal variability of dust precipitation in a low polluted city-the example of Karlsruhe/Germany. Environ Monit Assess 93:203–228. https://doi.org/10.1023/B:EMAS.0000016803.95952.b2

Ntzala G, Koukoulakis PH, Papadopoulos A, Leotsinidis M, Sazakli E, Kalavrouziotis I (2012) Interrelationships of pollution load index, transfer factor, and concentration factor under the effect of sludge. Environ Monit Assess 185:5231–5242. https://doi.org/10.1007/s10661-012-2939-8.

Pickering WF (1986) Matal ion speciation-Soil and sediments. Ore Geol Rev 1:83-146. https://doi.org/10.1016/0169-1368(86)90006-5

Pruvot C, Douay F, Herve F, Waterlot C (2006) Heavy metals in soil, crops and grass as a source of human exposure in the former mining areas. J Soils Sediments 6:215-220. https://doi.org/10.1065/jss2006.10.186

Reboredo FH, Pelica J, Lidon FC, Ramalho JC, Pessoa MF, Calvão T, Guerra M (2018) Heavy metal content of edible plants collected close to an area of intense mining activity (southern Portugal). Environ Monit Assess 190:484. https://doi.org/10.1007/s10661-018-6844-7

Rezaeian M, Moghadam MT, Kiaei MM, Zadeh HM (2020) The efect of heavy metals on the nutritional value of Alfalfa: comparison of nutrients and heavy metals of Alfalfa (*Medicago sativa*) in industrial and non-industrial areas. Toxicol Res 36:183-193. https://doi.org/10.1007/s43188-019-00012-6.

Martin S, Wendy G (2009) Human health effects of heavy metals. Environ Sci Technol Briefs Citizens 15:1–6.

Salvati L, Ferrara C, Ranalli F (2014) Changes at the fringe: Soil quality and environmental vulnerability during intense urban expansion. Eurasian Soil Sci 47(10):1069–1075.

Scalenghe R, Marsan FA (2009) The anthropogenic sealing of soils in urban areas. Landsc. Urban Plan 90(1-2):1–10. https://doi.org/10.1016/j.landurbplan.2008.10.011

Segura-Muňoz SI, Takayanagui AMM, Trevilato TMB, Santos CB, Hering SE (2004) Trace Metal Distribution in Surface Soil in the Area of a Municipal Solid Waste Landfill and a Medical Waste Incinerator. Bull Environ Contam Toxicol 72:157–164. https://doi.org/10.1007/s00128-003-0254-3

Silva, E.F., Mlayah, A., Gomes, C., Noronha. F., Charef, A., Sequeira, C., Esteves, V., & Marques, A.R.F. (2010). Heavy elements in the phosphorites from Kalaat Khasba mine (North-western Tunisia) : Potential implications on the environment and human health. J Hazard Mater 182:232-245.https://doi.org/10,10,1016/j.hazmat.2010.06.020.

Song Y, Jin L, Wang X (2016) Cadmium absorption and transportation pathways in plants. Int J Phytoremediation 19:133-141. https://doi.org/10.1080/15226514.2016.1207598.

Sun X, Li H, Guo X, Sun Y, Li S (2018) Capacity of six shrub species to retain atmospheric particulates with different diameters. Environ Sci Pollut Res 25:2643–2650. https://doi.org/10.1007/s11356-017-0549-2.

Taleb A, Bouhache M, Rzozi SB (1998) Flore adventice des céréales d'automne au Maroc. Rev. maroc. des sci. agron. et vétérinaires 18:121-130.

Tejera García, N.A., Olivera, M., Iribarne, C., Lluch, C., 2004. Partial purification of a non-specific acid phosphatase in leaves and root nodules of Phaseolus vulgaris. Plant Physiol. Biochem. 42, 585–591. https://doi.org/10.1016/j.plaphy.2004.04.004

Thornton I, Farago M (1997) The geochemistry of arsenic. C. O. Abernathy et al. (eds.), Arsenic © Chapman & Hall.

Tiwari S and Lata C (2018) Heavy Metal Stress, Signaling, and Tolerance Due to Plant-Associated Microbes: An Overview. Front. Plant Sci. 9:452. https://doi:10.3389/fpls.2018.00452

Tomlinson DL, Wilson JG, Harris CR, Jeffrey DW (1980) Problems in the assessment of heavy-metal levels in estuaries and the formation of a pollution index. Helgolander Meeresunters 33:566–575. https://doi.org/10.1007/BF02414780.

Ugulu I, Unver M, Dogan Y (2016) Determination and comparison of heavy metal accumulation level of *Ficus carica* bark and leaf samples in Artvin, Turkey. Oxid Communi 39:765-775.

FAO, United Nations (2015) Population Division World Urbanization Prospects. Department of Economic and Social Affairs. The 2014 Revision, New York, (ST/ESA/SER.A/366).

Uzma R, Zahoor AB, Tahir A, Sofi K, Tajamul R (2018) A review on impact of cement dust on soil health with special reference to Kashmir, India. Int J Chem Sci 2:24-30.

Wang W, Liu J, Ren Y, Zhang L, Xue Y, Zhang L, He J (2020) Phytotoxicity Assessment of Copper Oxide Nanoparticles on the Germination, Early Seedling Growth, and Physiological Responses in Oryza sativa L.. Bull Environ Contam Toxicol 104:770–777. https://doi.org/10.1007/s00128-020-02850-9.

Wei B, Yang L (2010) A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. Microchem J 94:99–107. https://doi.org/10.1016/j.microc.2009.09.014

WHO/FAO (2001) Codex A, Intergovernmental Tfon Joint FAO/WHO Food Standard Programme Codex Alimentarius Commission Twentyfourth Session Geneva, 2–7 July 2001.

Wieczorek J, Baran A, Bubak A (2023) Mobility, bioaccumulation in plants, and risk assessment of metals in soils. Sci Total Environ 882: 163574. https://doi.org/10.1016/j.scitotenv.2023.163574

Wong CSC, Li X, Thornton I (2006) Urban environmental geochemistry of trace metals. Environ Pollut 142 :1-16. https://doi.org/10.1016/j.envpol.2005.09.004

Xian J, Sun D, Xu W, Han Y, Zheng J, Peng J, Yang S (2020) Urban air pollution monitoring using scanning Lidar. Environ Pollut 258:113696. https://doi.org/10.1016/j.envpol.2019.113696

Yuswir NS, Praveena SM, Aris AZ, Ismail SNS, Hashim Z (2015) *Health Risk Assessment of Heavy Metal in Urban Surface Soil (Klang District, Malaysia).* Bull Environ Contam Toxicol 95:80–89. *https://doi.org/10.1007/s00128-015-1544-2*

Zerrouqi Z, Sbaa M, Oujidi M, Ekharmouz M, Bengemra S, Zerrouqi A (2008) Assessment of cement's dust impact on the soil using principal component analysis and GIS. Int J Environ Sci Technol 5:125-134.

Zhang C, Sale PWG, Doronila AI, Clark GJ, Livesay C, Tang C (2014) Australian native plant species *Carpobrotus rossii* (Haw.) Schwantes shows the potential of cadmium phytoremediation. Environ Sci Pollut Res 21:9843–9851. https://doi.org/10.1007/s11356-014-2919-3

Zheng N, Wang Q, Zheng D (2007) Health Risk of Hg, Pb, Cd, Zn, and Cu to the Inhabitants around Huludao Zinc Plant in China via Consumption of Vegetables. Sci Total Environ 383:81–89. https://doi.org/10.1016/j.scitotenv.2007.05.002

Zgłobicki W, Telecka M, Skupiński S, Pasierbińska A, Kozieł M (2018) Assessment of heavy metal contamination levels of street dust in the city of Lublin, E Poland. Environ Earth Sci 77:774. doi:10.1007/s12665-018-7969-2

Statements and Declarations

Ethical Approval: Not applicable. This is an observational study and that no ethical approval is required.

Consent to Participate: Not applicable.

Consent to Publish: Not applicable.

Authors Contribution: All authors contributed to the study conception and design. [MB] and [EKH] designed, carried out experiments and wrote the manuscript; [BA] designed, checked and critically reviewed the manuscript.

Funding Not applicable, No funding was received.

Financial interests: The authors declare they have no financial interests.

Competing Interests: The authors declare that they have no known competing interests.

Data Availability: All data generated or analyzed during this study are included in this published article.

Experimental research and field studies on plants: The authors declare that the experiment, concerning experimental research and field studies on wild plants, was achieved in this work complied with relevant institutional, national, and international guidelines and legislation.

Permissions and Licenses: The authors declare that the research work (soil and plant sampling) carried out as part of this work was granted permission to carry out research work at our university institution. The sampling was carried out in unexploited wild areas.

Identification of the Plant Material: MANDRI Btissam achieved the identification of plants sampled and studied in this work. Sudied plants were chosen after an inventory in studied areas to determine common plants between these different areas.

Code Availability: Not applicable.

Table 1. Description of sampling strategy in the four studied areas in the region of Safi

Areas	Plants Species	Distance* (m)	Part sampled	Soils	Distance* (m)	deep (cm)	Main Contamination Source
CA	***Eucalyptus globulus***	-	Shoot	**Soil 1**	20	0-15	**no contamination sources**
	Nerium oleander	-	Shoot	**Soil 2**	200	0-15	
	Ficus carica	-	Shoot	**Soil 3**	400	0-15	
	Medicago sativa	-	Shoot and root	**Soil 4**	600	0-15	
	Sinapis arvensis L.	-	Shoot and root	**Soil 5**	800	0-15	
	Carpobrotus edulis	-	Shoot	**Soil 6**	1000	0-15	
SF	***Eucalyptus globulus***	100-600	Shoot	**Soil 1**	20	0-15	**Cement Factory**
	Nerium oleander	100-500	Shoot	**Soil 2**	200	0-15	
	Ficus carica	200-1000	Shoot	**Soil 3**	400	0-15	
	Medicago sativa	100-600	Shoot and root	**Soil 4**	600	0-15	
	Sinapis arvensis L.	100-600	Shoot and root	**Soil 5**	800	0-15	
	Carpobrotus edulis	50-500	Shoot	**Soil 6**	1000	0-15	
UL	***Eucalyptus globulus***	20-600	Shoot	**Soil 1**	20	0-15	**Uncontrolled landfill**
	Nerium oleander	100-600	Shoot	**Soil 2**	200	0-15	
	Ficus carica	100-1000	Shoot	**Soil 3**	400	0-15	
	Medicago sativa	100-600	Shoot and root	**Soil 4**	600	0-15	
	Sinapis arvensis L.	100-600	Shoot and root	**Soil 5**	800	0-15	
	Carpobrotus edulis	100-600	Shoot	**Soil 6**	1000	0-15	
TP	***Eucalyptus globulus***	20-600	Shoot	**Soil 1**	20	0-15	**Phosphoric acid and fertilizers production unit**
	Nerium oleander	100-600	Shoot	**Soil 2**	200	0-15	
	Ficus carica	100-1000	Shoot	**Soil 3**	400	0-15	
	Medicago sativa	100-600	Shoot and root	**Soil 4**	600	0-15	
	Sinapis arvensis L.	100-600	Shoot and root	**Soil 5**	800	0-15	
	Carpobrotus edulis	100-600	Shoot	**Soil 6**	1000	0-15	

* Distance between the potential source of pollution and the sampling point, *SF: located in the vicinity of cement factory, UL: located near an uncontrolled landfill in a suburban area of Safi city, TP: located in the vicinity of treatment and transformation unit of phosphate, CA: A not influenced area or Control area*

Table 2. Contamination factor class and level us described by Hakanson (1980).

CF Values	Contamination Factor level
CF < 1	Low contamination
$1 \leq CF<3$	Moderate contamination
$3 \leq CF<6$	Considerable contamination
$CF \geq 6$	Very high contamination

Table 3. Agronomic proprieties of soils studied in different studied areas.

Area	Soil	pH (H_2O)	Cond. mS/cm	TOC (g kg^{-1})	NTK (g kg^{-1})	P(Olsen) (mg kg^{-1})
CA	**Soil 1**	7.2	0.23	17.2	0.70	0.40
	Soil 2	7.2	0.26	15.4	0.60	0.62
	Soil 3	7.3	0.25	17.8	0.55	0.25
	Soil 4	7.0	0.24	15.0	0.71	0.71
	Soil 5	7.2	0.25	16.0	0.67	0.39
	Soil 6	7.1	0.25	14.2	0.71	0.59
SF	**Soil 1**	7.5	0.39	16.0	0.76	0.75
	Soil 2	8.1	0.27	15.3	0.69	0.70
	Soil 3	8.2	0.22	18.2	1.52**	0.69
	Soil 4	8.1	0.21	19.7	1.07	0.70
	Soil 5	7.8	0.16	17.0	0.67	0.53
	Soil 6	7.6	0.26	18.4	0.77	0.64
UL	**Soil 1**	6.8	11.4**	47.5	2.30**	3.9**
	Soil 2	7.7	4.2**	30.0	1.92**	1.8**
	Soil 3	7.4	1.18	22.0	0.86	0.83
	Soil 4	7.5	0.49	19.0	0.80	0.75
	Soil 5	6.8	1.2	20.1	0.91	0.76
	Soil 6	7.5	0.23	18.9	0.83	0.78
TP	**Soil 1**	8.4	2.0	12.0	0.45	2.50**
	Soil 2	8.8	39.1**	15.3	0.61	2.29**
	Soil 3	8.2	3.4**	15.0	0.64	0.74
	Soil 4	8.1	2.7	13.0	0.51	0.86
	Soil 5	8.4	1.7	19.5	0.88	0.78
	Soil 6	8.8	0.5	17.0	0.56	0.71

*SF: located in the vicinity of cement factory, UL: located near an uncontrolled landfill in a suburban area of Safi city, TP: located in the vicinity of treatment and transformation unit of phosphate, CA: A not influenced area; **: significant differences at $p < 0.05$.*

Table 4. Total concentrations of measured metallic trace elements (mg kg^{-1}) of studies topsoils.

Area	Soil	Cd	Cu	Cr	Pb	Zn
CA	**Soil 1**	0.1	8.1	15.0	0.50	28.0
	Soil 2	<0.002	9.8	18.9	0.32	30.0
	Soil 3	<0.002	11.4	12.3	0.70	24.9
	Soil 4	<0.002	13.0	19.1	0.61	32.0
	Soil 5	0.1	8.1	12.7	0.41	22.5
	Soil 6	<0.002	5.8	13.9	0.52	23.0
SF	**Soil 1**	0.43**	13.0	24.3	1.8	49.0
	Soil 2	0.2	11.4	22.9	0.88	33.1
	Soil 3	0.26	14.7	17.3	0.72	28.6
	Soil 4	<0.002	14.7	16.2	0.60	24.9
	Soil 5	<0.002	11.4	15.2	0.51	21.8
	Soil 6	0.1	11.4	16.1	0.3	22.0
UL	**Soil 1**	0.5	24.4**	78.5**	3.9**	88.9**
	Soil 2	0.26	21.2**	45.7	3.2**	60.5
	Soil 3	<0.002	16.3	50.4	1.3	44.2
	Soil 4	0.1	22.8**	24.8	1.5	28.9
	Soil 5	<0.002	17.9	12.9	1.05	17.0
	Soil 6	<0.002	13.0	9.1	0.8	10.3
TP	**Soil 1**	1.8**	30.9**	102.0**	4.8**	148.7**
	Soil 2	0.5	27.7**	90.0**	2.3	96.3**
	Soil 3	0.66	24.4**	85.9**	1.4	79.8**
	Soil 4	<0.002	27.7**	89.1**	1.6	90.6**
	Soil 5	0.2	26.0**	69.5**	1.5	70.6**
	Soil 6	<0.002	24.4**	54.9**	1.2	71.2**

SF: located in the vicinity of cement factory, UL: located near an uncontrolled landfill in a suburban area of Safi city,
TP: located in the vicinity of treatment and transformation unit of phosphate, CA: A not influenced area;
***: significant differences at p <0.05.*

Table 5. Total concentrations of measured metallic trace elements (mg kg^{-1} DW) of studies plants.

Area	Plant	Cd	Cu	Cr	Pb	Zn
CA	***Eucalyptus globulus***	0.09	0.536	0.8	0.2	5.1
	Nerium oleander	<0.002	0.54	<0.005	<0.001	3.7
	Ficus carica	<0.002	0.498	<0.005	0,1	4.5
	Medicago sativa	<0.002	0.476	<0.005	<0.001	9.1
	Sinapis arvensis L.	<0.002	0.508	0.6	<0.001	11.0**
	Carpobrotus edulis	<0.002	0.52	<0.005	<0.001	3.1
SF	***Eucalyptus globulus***	<0.002	0.729	1.6	0.81	8.1
	Nerium oleander	0.1	0.878	1.0	0.42	5.0
	Ficus carica	0.1	0.732	1.1	0.75	9.5
	Medicago sativa	<0.002	0.726	0.90	0.90	4.5
	Sinapis arvensis L.	0.2	1.228**	0.98	0.82	4.7
	Carpobrotus edulis	<0.002	0.588	0.66	0.40	2.6
UL	***Eucalyptus globulus***	<0.002	0.661	1.0**	0.5	6.1
	Nerium oleander	0.1	0.718	0.9**	0.3	4.7
	Ficus carica	<0.002	0.572	1.2**	0.4	3.5
	Medicago sativa	<0.002	0.588	0.8	0.76	2.5
	Sinapis arvensis L.	<0.002	0.56	0.9**	0.52	3.7
	Carpobrotus edulis	<0.002	0.53	0.6	0.28	1.6
TP	***Eucalyptus globulus***	0.2	1.204**	2.0**	1.7**	19.9**
	Nerium oleander	0.15	0.925	1.8**	0.7	5.9
	Ficus carica	0.1	0.864	1.5**	0.85	10.5**
	Medicago sativa	<0.002	0.978	1.0**	0.96**	6.5
	Sinapis arvensis L.	0.4**	1.826**	1.3**	0.92**	7.0
	Carpobrotus edulis	0.3**	1.792**	0.8	0.80	4.1

*SF: located in the vicinity of cement factory, UL: located near an uncontrolled landfill in a suburban area of Safi city, TP: located in the vicinity of treatment and transformation unit of phosphate, CA: A not influenced area;**: significant differences at* $p < 0.05$.

Table 6. Pearson's correlation matrix for agronomic proprieties of soils and average content of Metallic trace elements in soils and in plants.

	pH	Cond.	TOC	NTK	P(Olsen)	Cd_Soil	Cu_Soil	Cr_Soil	Pb_Soil	Zn_Soil	Cd_Plant	Cu_Plant	Cr_Plant	Pb_Plant	Zn_Plant
pH	1														
Cond.	0.72291	1													
TOC	-0.49155	-0.10098	1												
NTK	-0.44773	-0.24991	0.96001	1											
P(Olsen)	0.29226	0.74089	0.58985	0.45865	1										
Cd_Soil	0.88216	0.96302	-0.25143	-0.33470	0.62515	1									
Cu_Soil	0.71033	0.96997	0.08571	-0.03191	0.85287	0.94040	1								
Cr_Soil	0.76970	0.99748	-0.15025	-0.28424	0.70925	0.97944	0.96633	1							
Pb_Soil	0.47056	0.86855	0.39762	0.26172	0.97543	0.78011	0.94636	0.84649	1						
Zn_Soil	0.81105	0.98616	-0.25306	-0.37722	0.63175	0.98697	0.93767	0.99442	0.78658	1					
Cd_Plant	0.96500	0.86242	-0.47251	-0.50333	0.40256	0.96236	0.81659	0.89598	0.58854	0.93000	1				
Cu_Plant	0.98273	0.83579	-0.44481	-0.45273	0.40561	0.95194	0.80915	0.87255	0,5853	0.90513	0.99556	1			
Cr_Plant	0.97036	0.83986	-0.29651	-0.29309	0.51445	0,95182	0.85443	0.87355	0.66929	0.89134	0.96944	0.98505	1		
Pb_Plant	0.95954	0.75521	-0.22815	-0.18300	0.50145	0.89142	0.80530	0.79309	0.63720	0.80696	0.91812	0.94948	0.98506	1	
Zn_Plant	0.80177	0.64358	-0.82598	-0.87324	-0.03234	0.74422	0.48730	0.68139	0.18819	0.75430	0.86011	0.82608	0,71671	0.61991	1

Table 7. Metallic trace elements Bioaccumulation Factor for plants

Area	Plant	Cd	Cu	Cr	Pb	Zn
CA	*Eucalyptus globulus*	0.9**	0.06	0.05	0.4	0.2
	Nerium oleander	-	0.06	-	-	0.1
	Ficus carica	-	0.05	-	0.2	0.2
	Medicago sativa	-	0.05	-	-	0.3
	Sinapis arvensis L.	-	0.05	0.04	-	0.4
	Carpobrotus edulis	-	0.06	-	-	0.1
SF	*Eucalyptus globulus*	-	0.06	0.09	1.0**	0.3
	Nerium oleander	0.4	0.07	0.05	0.5	0.2
	Ficus carica	0.4	0.06	0.06	0.9**	0.3
	Medicago sativa	-	0.06	0.05	1.1**	0.2
	Sinapis arvensis L.	0.8**	0.1	0.05	1.0**	0.2
	Carpobrotus edulis	-	0.05	0.04	0.5	0.09
UL	*Eucalyptus globulus*	-	0.03	0.03	0.3	0.2
	Nerium oleander	0.4	0.04	0.02	0.2	0.1
	Ficus carica	-	0.03	0.03	0.2	0.08
	Medicago sativa	-	0.03	0.02	0.4	0.06
	Sinapis arvensis L.	-	0.03	0.02	0.3	0.08
	Carpobrotus edulis	-	0.03	0.02	0.1	0.03
TP	*Eucalyptus globulus*	0.3	0.05	0.02	0.8**	0.2
	Nerium oleander	0.2	0.03	0.02	0.3	0.06
	Ficus carica	0.1	0.03	0.02	0.4	0.1
	Medicago sativa	-	0.04	0.01	0.5	0.07
	Sinapis arvensis L.	0.5	0.07	0.02	0.4	0.08
	Carpobrotus edulis	0.4	0.07	0.01	0.4	0.04

*SF: located in the vicinity of cement factory, UL: located near an uncontrolled landfill in a suburban area of Safi city, TP: located in the vicinity of treatment and transformation unit of phosphate, CA: A not influenced area; **: significant differences at $p < 0.05$.*

Table 8. Contamination Factor according to studied areas

Area	Soil	Cd	Cu	Cr	Pb	Zn
SF	**Soil 1**	4.3**	1.4	1.6	3.5**	1.8
	Soil 2	2.0	1.8	1.5	1.7	1.2
	Soil 3	2.6	1.6	1.1	1.4	1.1
	Soil 4	nd	1.6	1.1	1.2	0.9
	Soil 5	nd	1.2	1.0	1,0	0.8
	Soil 6	1.0	1.2	1.0	0.6	0.8
UL	**Soil 1**	2.0	1.9	4.2**	4.9**	3.0**
	Soil 2	1.1	1.7	2.4	4.4**	2.0
	Soil 3	nd	1.3	2.7	1.6	1.5
	Soil 4	0.4	1.8	1.3	1.9	1.0
	Soil 5	nd	1.4	0.7	1.3	0.6
	Soil 6	1.0	1.0	0.5	1.0	0.3
TP	**Soil 1**	6.3**	1.6	2.8	2.5	3.6**
	Soil 2	1.7	1.4	2.4	1.2	2.3
	Soil 3	2.3	1.2	2.3	0.7	1.9
	Soil 4	nd	1.4	2.4	0.8	2.2
	Soil 5	0.7	1.3	1.9	0.8	1.7
	Soil 6	1.2	1.5	1.5	0.6	1.7

*SF: located in the vicinity of cement factory, UL: located near an uncontrolled landfill in a suburban area of Safi city, TP: located in the vicinity of treatment and transformation unit of phosphate, nd: not determined, **: significant differences at p <0.05.*

Table 9. Metallic trace elements concentration (mg L^{-1}) in leaves rinsing water of plants

Area	Plant	Cd	Cu	Cr	Pb	Zn
	Eucalyptus globulus	<0.002	<0.004	<0.005	<0.001	<0.003
	Nerium oleander	<0.002	<0.004	<0.005	<0.001	<0.003
CA	***Ficus carica***	<0.002	<0.004	<0.005	<0.001	<0.003
	Medicago sativa	<0.002	<0.004	<0.005	<0.001	<0.003
	Sinapis arvensis L.	<0.002	<0.004	<0.005	<0.001	<0.003
	Carpobrotus edulis	<0.002	<0.004	<0.005	<0.001	<0.003
	Eucalyptus globulus	<0.002	<0.004	<0.005	**0.15****	<0.003
	Nerium oleander	<0.002	<0.004	<0.005	<0.001	<0.003
SF	***Ficus carica***	<0.002	<0.004	<0.005	**0.09**	<0.003
	Medicago sativa	<0.002	<0.004	<0.005	<0.001	<0.003
	Sinapis arvensis L.	<0.002	<0.004	<0.005	<0.001	<0.003
	Carpobrotus edulis	<0.002	<0.004	<0.005	<0.001	<0.003
	Eucalyptus globulus	<0.002	<0.004	<0.005	<0.001	<0.003
	Nerium oleander	<0.002	<0.004	<0.005	<0.001	<0.003
UL	***Ficus carica***	<0.002	<0.004	<0.005	<0.001	<0.003
	Medicago sativa	<0.002	<0.004	<0.005	<0.001	<0.003
	Sinapis arvensis L.	<0.002	<0.004	<0.005	<0.001	<0.003
	Carpobrotus edulis	<0.002	<0.004	<0.005	<0.001	<0.003
	Eucalyptus globulus	**0,08**	**0.07**	**0.1****	**0.4****	**0.9****
	Nerium oleander	<0.002	<0.004	<0.005	<0.001	<dl
TP	***Ficus carica***	**0.07**	<0.004	<0.005	**0.2****	**0.5****
	Medicago sativa	<0.002	<0.004	<0.005	<0.001	<0.003
	Sinapis arvensis L.	<0.002	<0.004	<0.005	<0.001	<0.003
	Carpobrotus edulis	<0.002	<0.004	<0.005	<0.001	**0.3****

*SF: located in the vicinity of cement factory, UL: located near an uncontrolled landfill in a suburban area of Safi city, TP: located in the vicinity of treatment and transformation unit of phosphate, CA: A not influenced area, <dl: less than detection limit, **: significant differences at p <0.05.*

Table 10: Average phosphatase activity (µmol Pi $min^{-1}g^{-1}$) measured in leaves of studied plants

	CA	SF	UL	TP
Eucalyptus globulus	0.7±0.05	0.6±0.02	0.5±0.02	0.5±0.01
Nerium oleander	0.6±0.02	0.7±0.01	0.6±0.01	0.4±0.01
Ficus carica	0.9±0.04**	0.8±0.03	0.8±0.05	0.3±0.01
Medicago sativa	2.5±0.09**	1.7±0.05**	1.1±0.06	0.8±0.05
Sinapis arvensis L.	1.8±0.05**	1.9±0.05**	1.5±0.01**	0.9±0.05
Carpobrotus edulis	0.9±0.03	0.8±0.01	0.5±0.01	0.4±0.03

*SF: located in the vicinity of cement factory, UL: located near an uncontrolled landfill in a suburban area of Safi city, TP: located in the vicinity of treatment and transformation unit of phosphate, CA: A not influenced area, **: significant differences at p <0.05.*

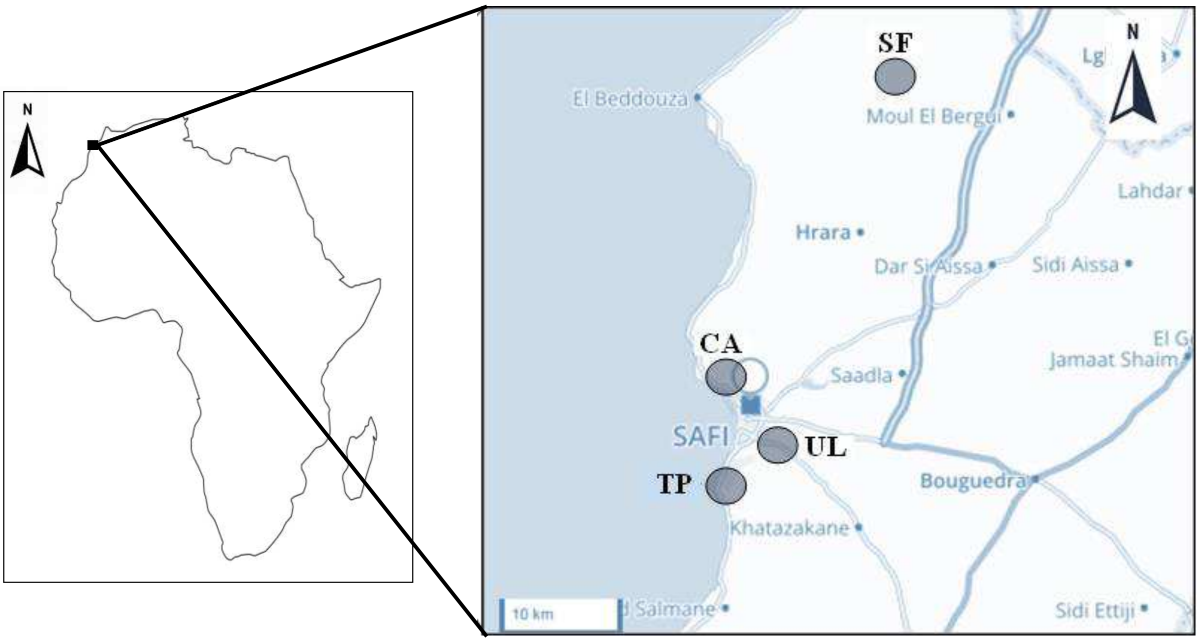

Fig. 1. Localization of sampling areas in the region of Safi

SF: located in the vicinity of cement factory, UL: located near an uncontrolled landfill in a suburban area of Safi city, TP: located in the vicinity of treatment and transformation unit of phosphate, CA: A not influenced area

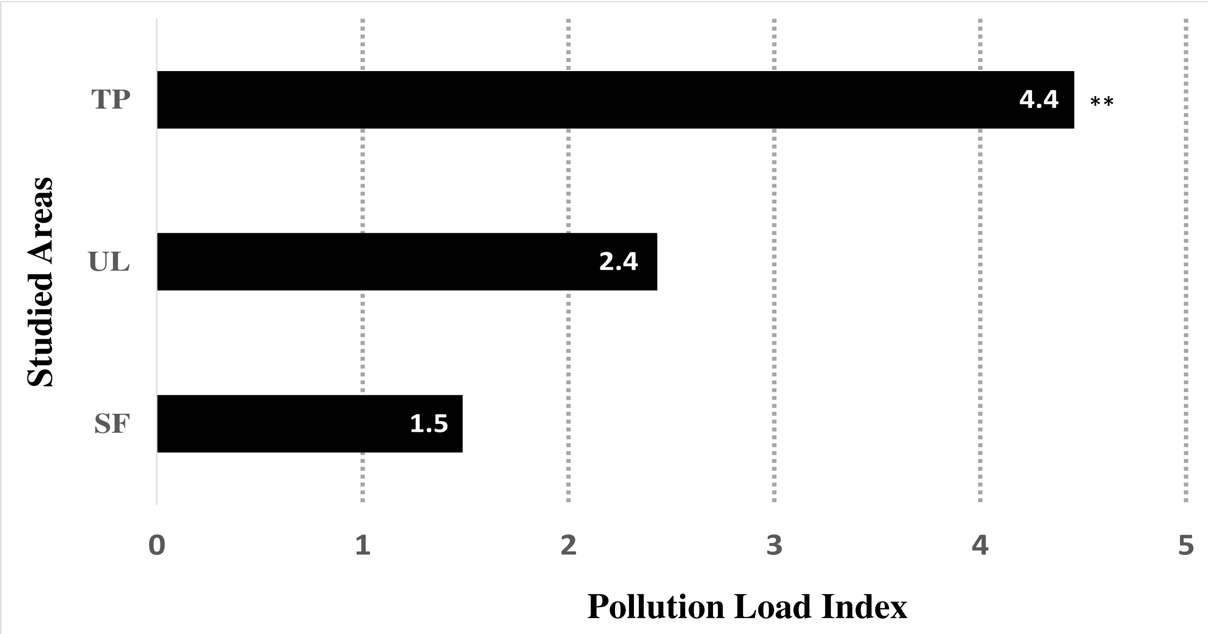

Fig. 2. Pollution Load Index calculated for studied areas in the region of Safi
*SF: located in the vicinity of cement factory, UL: located near an uncontrolled landfill in a suburban area of Safi city, TP: located in the vicinity of treatment and transformation, **: significant differences at p <0.05.*

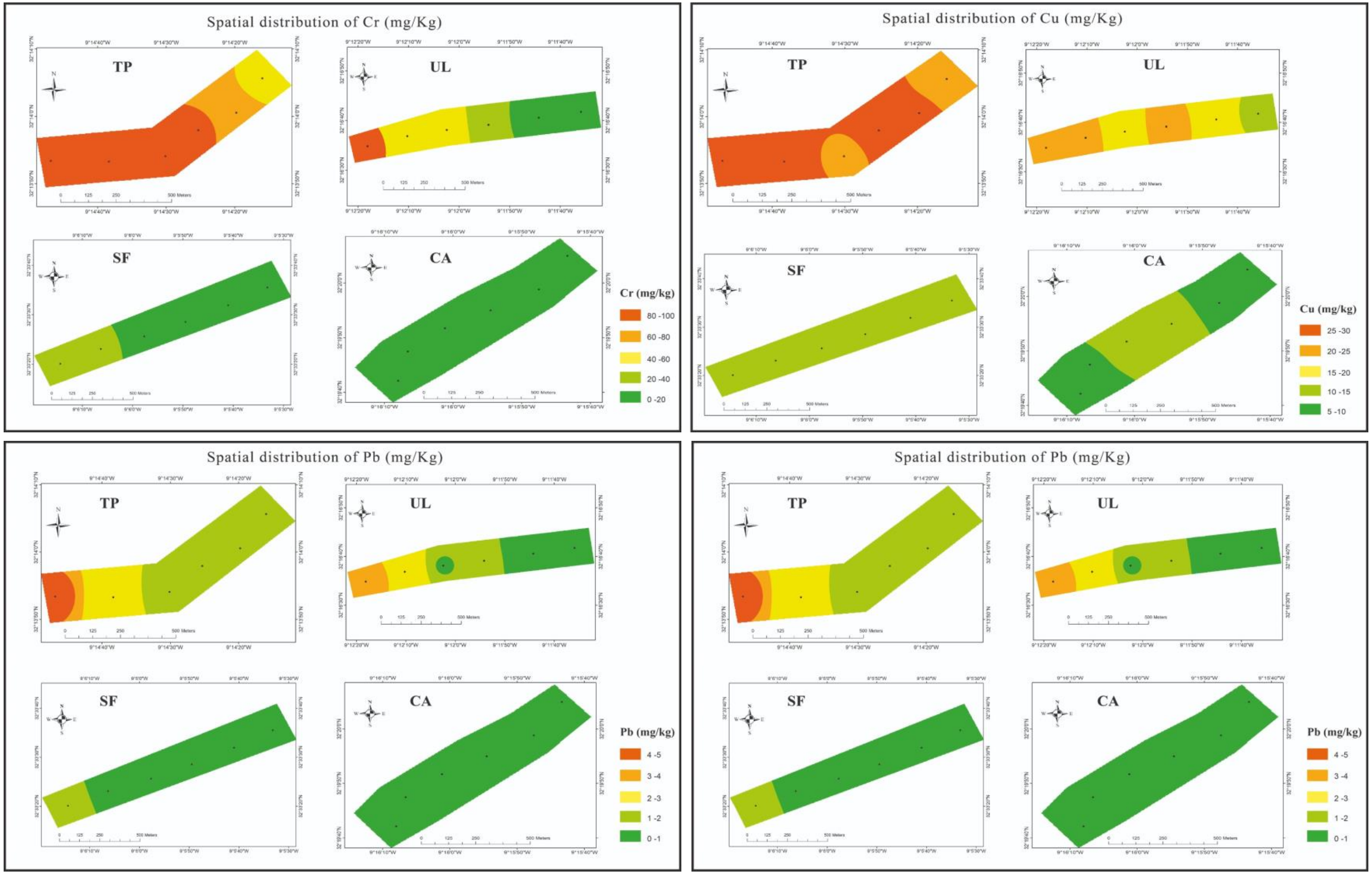

Fig. 3. Spatial distribution of Cr, Cu, Pd and Zn in studied urban and suburban areas in the region of Safi

SF: located in the vicinity of cement factory, UL: located near an uncontrolled landfill in a suburban area of Safi city, TP: located in the vicinity of treatment and transformation unit of phosphate, CA: A not influenced area

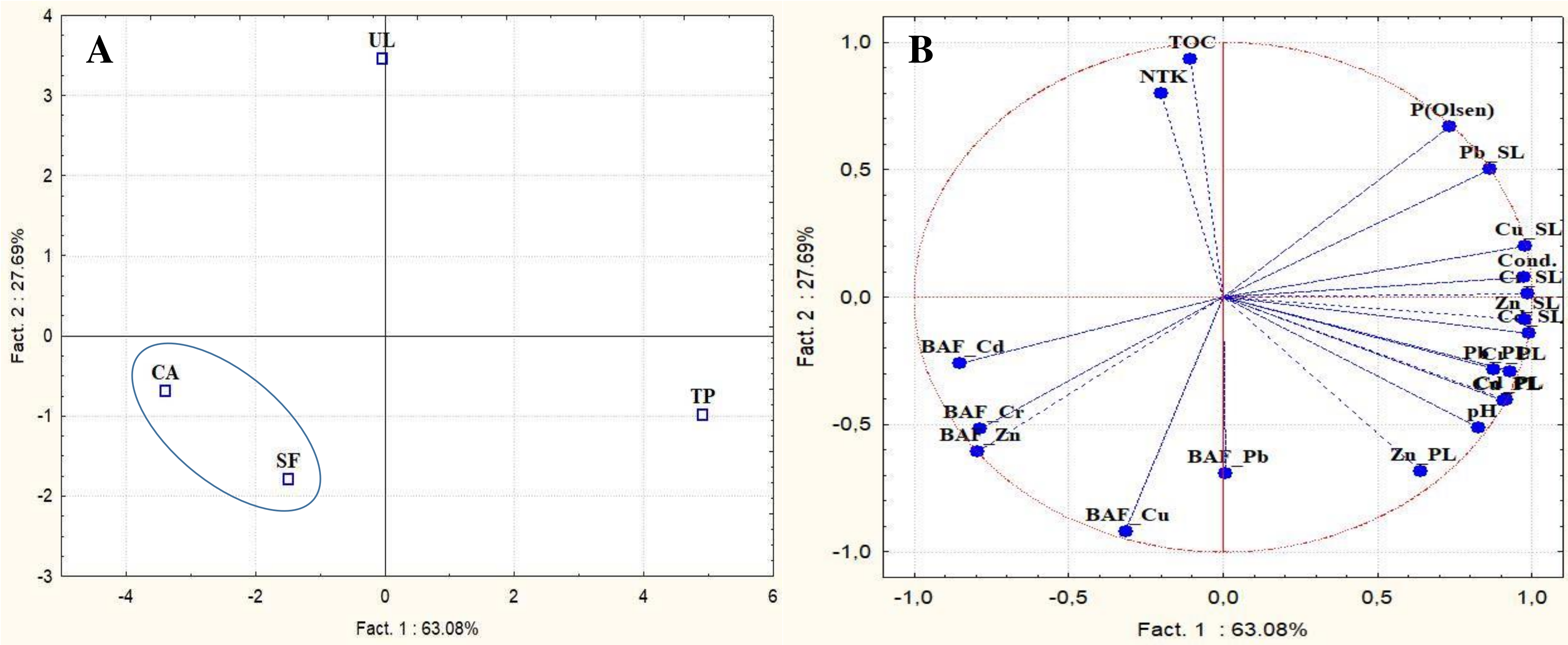

Fig. 4. Principal Component Analysis achieved for studied urban and suburban areas.

SF: located in the vicinity of cement factory, UL: located near an uncontrolled landfill in a suburban area of Safi city,
TP: located in the vicinity of treatment and transformation unit of phosphate, CA: A not influenced area, Metal_SL : Metal content in soil, Metal_PL: Metal content in plant, BAF_Metal : Bioaccumulation Factor for metal.