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Heavy Metal Contamination in Agricultural Soils: A Case Study in Mohammedia Benslimane Region (Morocco)

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ABSTRACT

This research aimed to determine the physicochemical characteristics and heavy metal concentrations of agricultural soils used for grape and wheat production in Morocco in the Mohammedia Benslimane area. The organic matter (OM) content ranged from 0.6% to 2.93%. The degree of total nitrogen was higher in the wheat plots than in the vine plots in the Mohammedia and Benslimane regions. Total nitrogen average rates ranged from 0.04 to 0.5% and from 0.07 to 0.8% in the vine and wheat plots. These results imply that the soil was silty clay and clay texture, neutral to slightly acidic at all stations. The P_2O_5 concentrations were 11.15 ppm and 68.14 ppm under the vine and the wheat plots, respectively, while the potassium concentration ranged from 33.1 to 287.9 ppm and from 26.9 to 184.75 ppm under the vine and the wheat plots, respectively. Furthermore, the concentrations of Cd at a few stations exceeded the standard value (2 ppm), reaching 10.375 ppm. The Pb and Zn concentrations were higher in vineyard plots than in wheat plots. The Pb and Zn concentrations were 20.22 ppm and 148.60 ppm, respectively. This study reports updated information on the states of eight stations in Mohammedia and Benslimane. However, further research is necessary to determine the pollution factors in local practice crops and naturally growing plants at these stations to assess their impact on livestock and humans.

Keywords: pollution, soil, wheat, heavy metals, vine.

INTRODUCTION

It has been proven that most environmental problems worldwide are due to the contamination of soils with heavy metals (Hazrat et al., 2019; Jiang et al., 2019). The degradation and poisoning of soils have recently become natural sources of danger for rural and urban people (Charlesworth et al., 2003; Imperqto et al., 2003). Industrial activities have a serious impact on the global environment through the daily waste generated by the discharge of commercial and agricultural wastewater, domestic sewage discharge, and atmospheric deposition, all of which affect plant, animal, and human health (Khan et al., 2004; Yan et al., 2018). When the wind blows, the dust particles in the top layer of the soil, containing toxic particles, become harmful once inhaled by humans (Alghobar et Suresha, 2017). Furthermore, toxic particles accumulate in minor particle length fractions in soils (Li et al., 2001; Manta et al., 2002; Komarniki, 2005).

Heavy metals cause contamination of agricultural soils and crops, which leads to serious environmental problems because of their non-biodegradability, biological half-life, and ability to accumulate in different parts of human and plant tissues (Kachenko & Singh, 2006; Radwan & Salama, 2006; Khan et al., 2010; Muhammad et al., 2011).

In plants, heavy metal contamination causes alterations in metabolism and physiological and biochemical processes, which leads to growth reduction and lower biomass production (Nagajyoti et al., 2010). In humans, exposure to high levels of heavy metals causes several diseases, including cancer, immune problems, acute stomach, intestinal aches, and liver damage (Harmanescu et al., 2011; Rahman et al., 2014).

Soil quality appears to be an excellent predictor of long-term land management success (Herrick, 2000). Soil is essential for almost all land uses (Koch et al., 2013). Soil quality refers to the ability of soil to support plant and animal productivity, maintain or improve water and air quality, as well as promote plant and animal health (Oberholzer et al., 2012; Adhikari and Hartemink, 2016). Morocco has consistently prioritized and strategically chosen to expand its agricultural industry. However, because the country is primarily arid and semi-arid, intensive agricultural expansion has increased agricultural production and degraded the soil quality. This deterioration poses a severe threat because it results in soil contamination and reduction in soil fertility. With the development of an ambitious agricultural policy called the Green Morocco Plan (GMP) in 2008, soil quality research in Morocco has become a hot topic. (Faysse, 2015). In the Mohammedia and Benslimane regions (Morocco), the growth of cereals has exceeded that of vines. This alternate rotation might have affected the first soil quality class in this region known for the vineyards introduced by the french protectorate.

To the best of our knowledge, this is the first study to highlight soil quality following a two-crop rotation (vineyard and cereals) in the Mohammedia and Benslimane regions. This study aimed to discover the soil traits within the agricultural soils below vines and wheat in these regions and to estimate the detailed soil properties below vines and wheat. In addition, an evaluation of the pollutants index as well as the correlation between biological parameters and trace metal elements were evaluated.

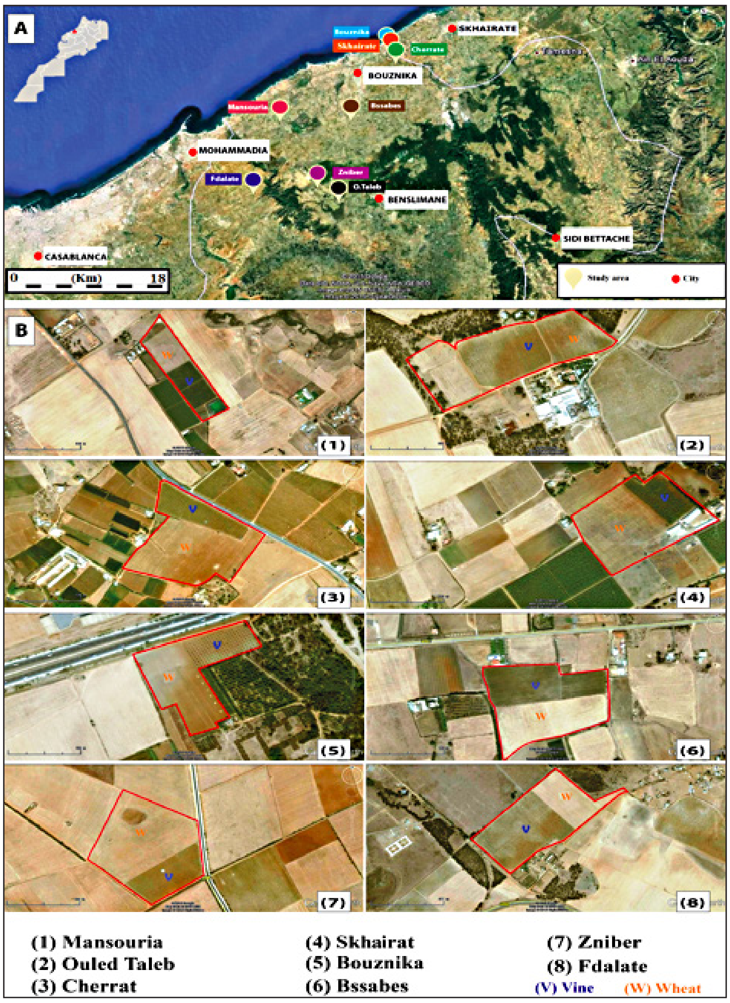

Figure 1. Location of samples in Mohammedia and Benslimane regions

MATERIALS AND METHODS

This research was conducted in some areas belonging to the province of Benslimane and the prefecture of Mohammedia, the region of Casablanca-Settat (Morocco) (Fig. 1). This area is positioned between two major cities in Morocco; the first is capital city Rabat, and the second is the economic city Casablanca. Regarding the climate, they are generally characterized by a semiarid Mediterranean climate (Amami et al.; 2010).

The investigation was conducted at eight stations (Bouznika, Bssabes, Cherrat, Fdalate, Mansouria, Skhairate, Zniber, and Ouled Taleb) in different regions of Mohammedia and Benslimane cities (Fig. 1). Ten samples were collected at every station in the horizon (0–20 cm).

The next step was to carry all these samples to the laboratory for analysis; therefore, the soil samples were air-dried and passed through a < 2 mm sieve.

Standard techniques were used to measure the physicochemical parameters of the samples. Soil texture analysis was performed at various stations by using the Robinson pipette method (AFNOR NF X31-107). Soil pH was measured using the H_2O (1:2.5 ratio) method of McLean (1982), while $CaCO_3$ was determined using the Bernard (Chamley, 1966) method.

The OM analysis was conducted using the Walkley and Black (1934) method. P_2O_5 was determined by tmeans of Olsen (1954) method, and exchangeable potassium was determined according to the method described by Lakanen and Ervio (1971). Total nitrogen content was determined using the Kjeldahl assay (Kjeldhal, 1995). Furthermore, the contents of six trace metals (Al, Fe, Cd, Cu, Pb, and Zn) were determined. The soil was extracted using aqua regia at -160 °C.

The metal concentrations in the digests were determined by inductively coupled plasma-atomic emission spectroscopy (ICP-AES; Perkin Elmer OPTIMA-2000, USA). Each test was performed in triplicate. The correlation analyses between variables were performed using Xlstat (2014).

RESULTS AND DISCUSSION

Physico-chemical properties of soils

In the Fdalate, Zniber, Bssabes, Skhairate, Bouznika, Cherrat, and Mansouria stations, a granulometric study revealed a clay texture. The Ouled Taleb station, on the other hand, had a silt loam texture (Fig. 2).

The pH is considered the main chemical parameter that controls the bioavailability of heavy metals in the soil (Brallier et al., 1996). The results of the H_2O (1:2.5 ratio) method showed that the pH values were neutral to slightly acidic at all the stations (Fig. 3). Soil pH values under wheat cultivation were higher than those under grapevine cultivation, except at Fdalate station. A high alkalization value was observed at the Skhairate station.

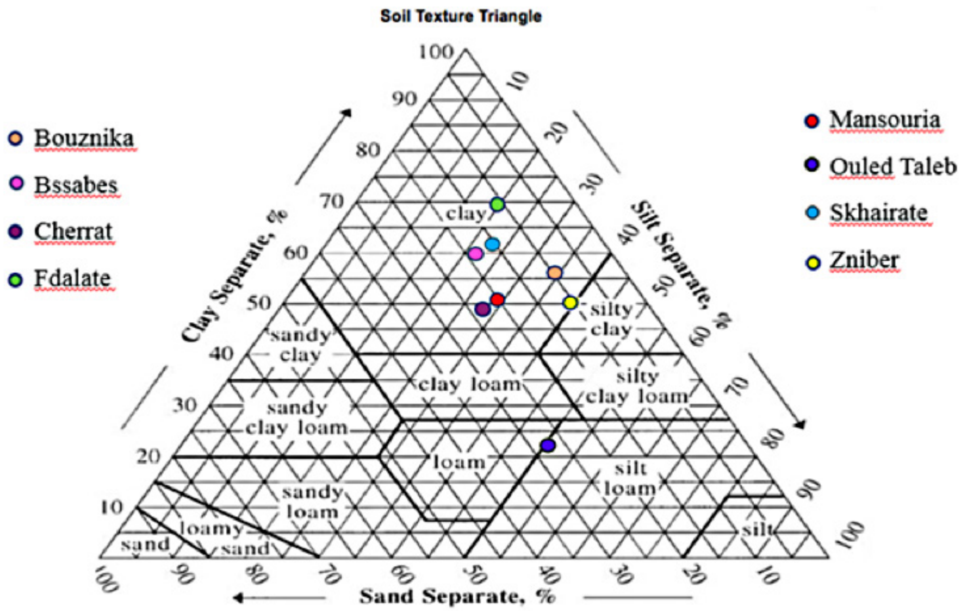

Figure 2. Soil texture of the study area

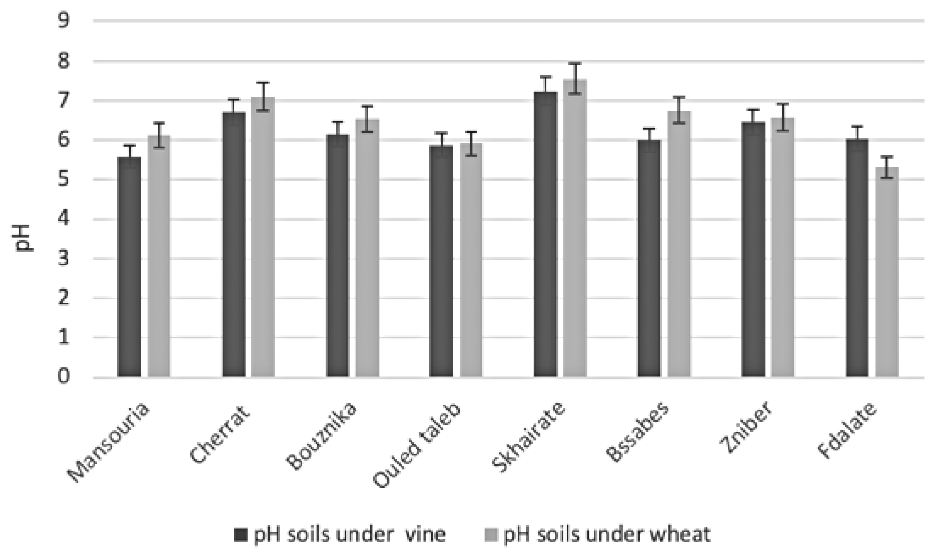

Figure 3. Soil pH according stations in Mohammedia and Benslimane regions

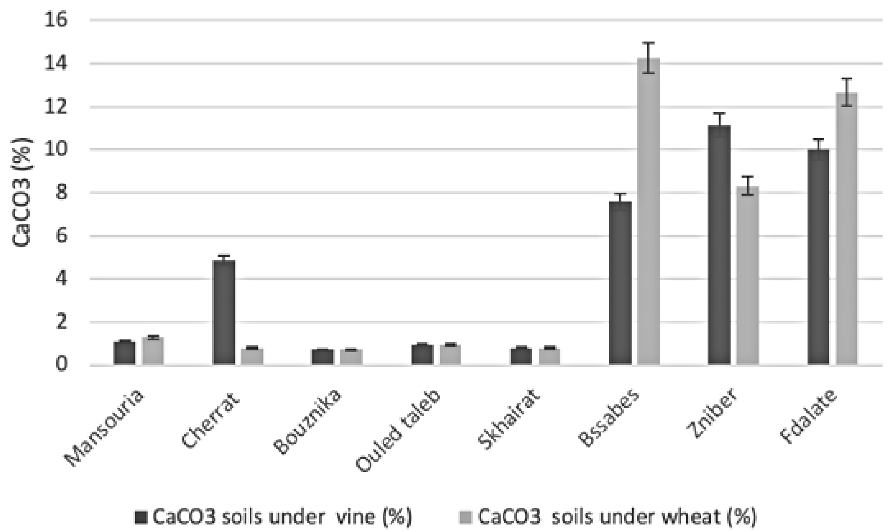

Figure 4. The $CaCO_3$ concentration in the studied soils

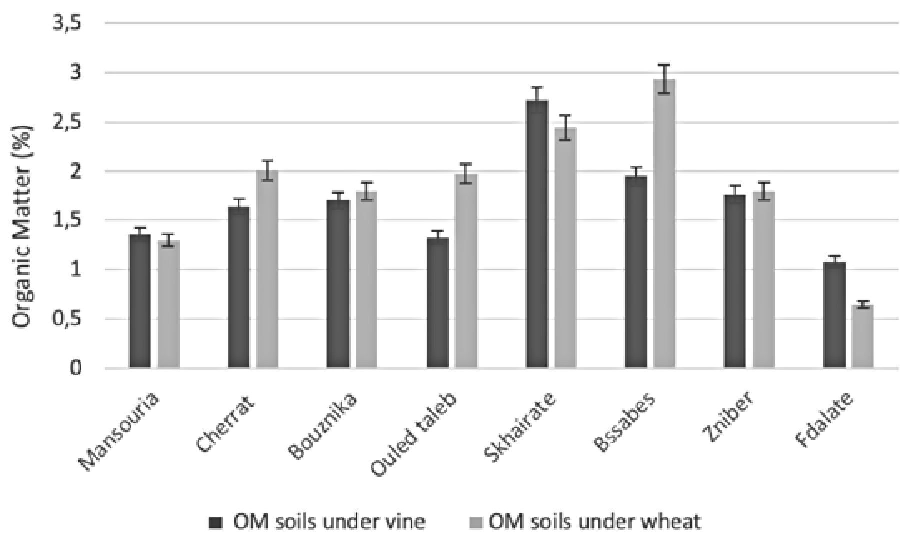

Figure 5. Soil organic matter content

Several studies have been conducted to determine the pH values in different soil regions of Morocco, especially in the soils under wheat (Badraoui et al., 1998; Bouabid & Moustaoui, 2005). Compared to the results obtained in those studies, the pH values in Bahira, Sais, and Moyen Atlas were similar (7.2, 7.6, and 7.8, respectively). However, Bouanan et al. (2012) and Moughli (2005), reported higher values in the Triffa plain (the Moulouya perimeter) and the Tadla area (8.30, and 8, respectively). Coll (2011), reported high pH values in vine soil (7.2, and 8.2, respectively). The alkalinity of soils is influenced by annual rainfall and the combination of the clay fraction with organic matter.

Figure 4 shows the $CaCO_3$ concentrations at all stations. The $CaCO_3$ content of the analyzed soil varied from 0.8% to 14.25%. These results can be explained by the predominance of neutral non-limestone rocks (schist) or acids (granite) in the soil characteristics of the Mohammedia and Benslimane regions (Ghanem, 1978). These results are comparable with those Bouabid and Moustaoui (2005) reported in the Sais region (8.4%). However, high $CaCO_3$ values were identified in the agricultural soils of the Middle Atlas (34.2%).

Organic matter (OM) is an essential component of soil fertility that improves soil quality by enhancing the formation of aggregates, maintaining their stability, and influencing the soil water stock in nutrients (Oldfield et al., 2018). Figure 5 summarizes the distribution of OM at all the stations. The results show that the OM rate varied from one plot to another. The average rate of OM in wheat plots was higher (2.93%) than in vineyards plots (1.7%), save for a patch of land planted with wheat near Skhairate, where organic fertilizer was available. These results were significantly lower than those reported by Bouabid and Moustaoui (2005) in the Sais region, with 3.28% as the average value of carbonic content. These results were compared with those recorded in the soils of Tadla (1.04%) (Moughli et al., 2005), Middle Atlas (1.9%) (Bouabid and Moustaoui, 2005). In a study conducted by Yaakoubi (2010), lower OM content values were reported in the soils under vines in the Meknes region (0.34%).

Nitrogen (N) is an essential element for plant nutrition. It influences the mineralization of organic matter, which provides the carbon and energy necessary for soil biology (Carranca et al., 2018). The results of the total nitrogen assay using the Kjeldahl method showed variable values from one station to another, and total nitrogen concentrations were in the range of 0.05%–0.8% (Fig. 6). The total nitrogen dosage of soils under vines and wheat was higher than that found by Yaakoubi, (2010) and Edahbi et al., (2014) in the agricultural soils of Meknes (0.01%) and Lokous (0.01%, and 0.05%, respectively).

In general, the total nitrogen rate was lower in the soils under vines than in wheat. This can be attributed to the mineralization of organic matter in wheat soils. N strongly influenced the development of the vine and the constitution of the grapes. Even in the absence of N fertilization, the vine N supply varies according to various parameters related to the type of soil, such as organic matter content, pH, lime content, and fertility index (C/N) (Trégoat et al., 2002).

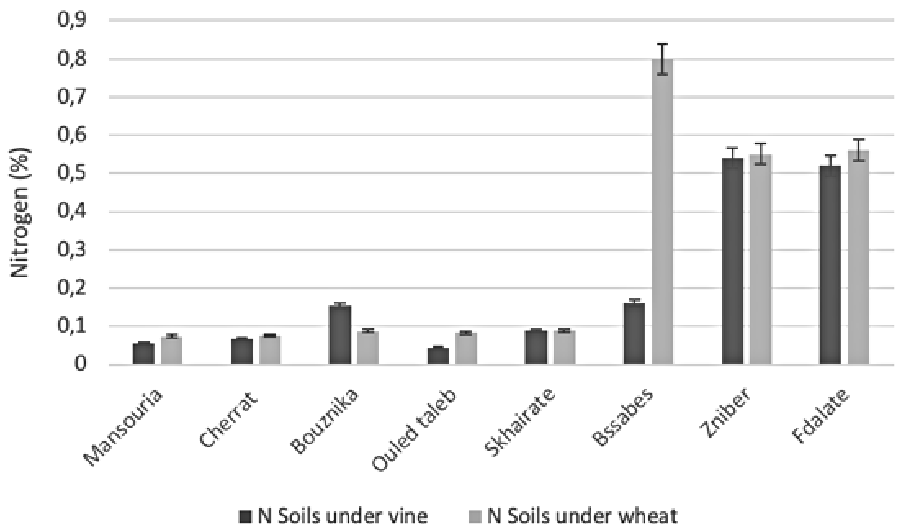

Figure 6. Soil nitrogen content

Phosphorus (P) is a fundamental element in plant nutrition and significantly influences crops (Ocio et al., 1991). Figure 7 summarizes the P concentrations in the studied soils. The plots have comparable phosphorus content between the vineyard and the wheat soils at Cherrat (50.21 ppm, and 49.23 ppm, respectively), Bouznika (11.57 ppm, and 12.13 ppm, respectively), Ouled Taleb (12.35 ppm, and 13.57 ppm, respectively), Skhairate (34.68 ppm, and 31.29 ppm, respectively), Bssabes (68.01 ppm, and 67.96 ppm, respectively), Zniber (68.17 ppm, and 68.03 ppm, respectively), and Fdalate stations (68.24 ppm, and 68.14 ppm, respectively). Only the Mansouria station showed a significant difference between the levels of available P (53.36 ppm, and 21.03 ppm, respectively). These levels indicate saturation of soils with P.

As compared to the results obtained in several studies, the average phosphorus contents in soils were high compared to other soils in Morocco, including the soils of Sais, Middle Atlas, Tadla, and Meknes with phosphorus contents of 11.2 ppm, 12.1 ppm, 19 ppm, and 20 ppm, respectively (Bouabid and Moustaoui., 2005; Moughli et al., 2005). The limestone in soils under vines and wheat at the Bssabes, Fdalate, and Zniber stations influences phosphorus assimilation in these soils by forming bonds between calcium and P provided by the fertilizers.

Potassium (K) is an essential element for plant development and plays an essential role in plant metabolism. The deficiency of this element in clay soils is rare (Gargouri et Mhiri., 2002). Figure 8 shows the K concentrations at all stations.

There was an exponential evolution of potassium concentrations from the station of

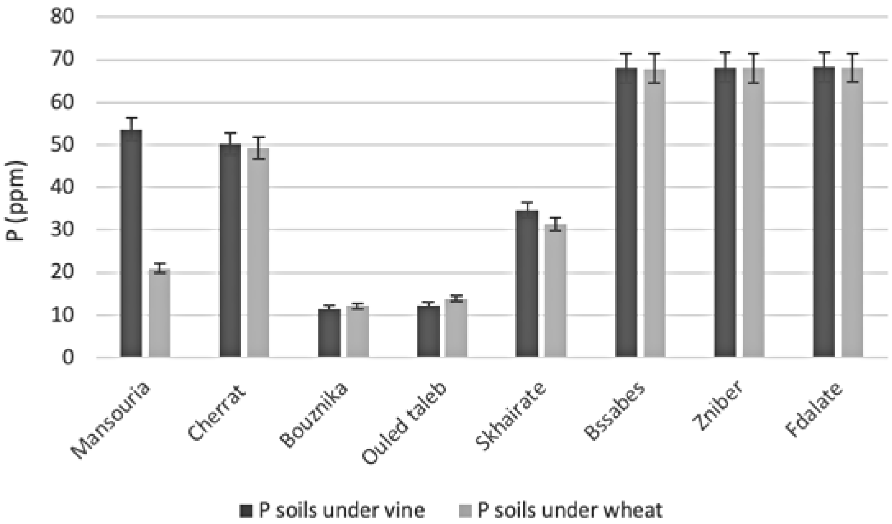

Figure 7. Phosphorus concentration in the studied soils

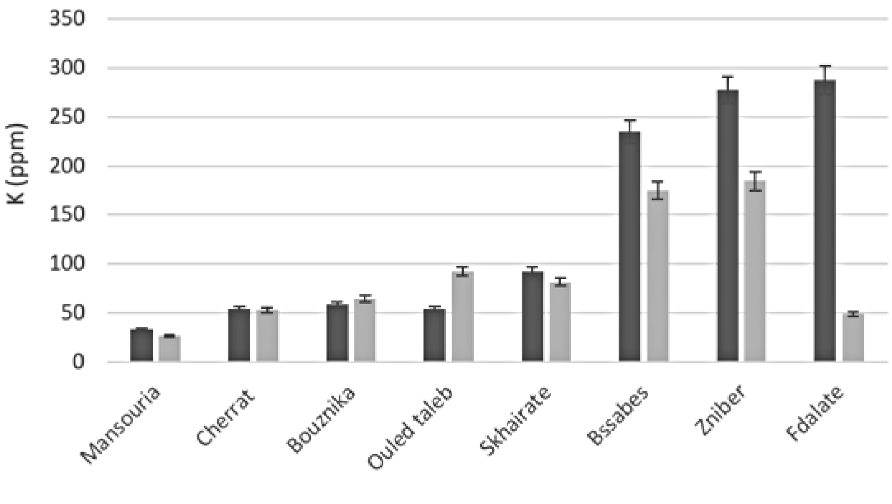

Figure 8. The potassium concentration in the studied soils

Mansouria to the station of Fdalate. The K values were equivalent between soils under vines and wheat at the Cherrate and Bouznika stations.

These results showed the richness of K in the soils studied at all stations. However, these contents were significantly lower than those reported by Bouabid and Moustaoui (2005) in the soils of Sais and the Middle Atlas, as well as by Moughli and co-workers (2005) in the Tadla (817 ppm, 353 ppm, and 467.9 ppm, respectively).

Cd, Cu, Pb, and Zn contamination in soil

The substantial accumulation of metal trace elements found in the soil is the result of heritage caused by changes in rock concentrations (local geochemical background), which are, to a certain extent, altered by the soil formation process. Human activities contribute to the enhancement of this background (Baize, 1997).

Figure 9 summarizes the Al values at all stations. The Al values were higher in the vineyard soils than in the wheat soils at all stations, except for Zniber, Fdalate, and Cherrat, with no significant difference between the soils beneath neath the vines and those under the cereals growing, which was manifested by significantly low values at the stations of Fdalate, Bssabes, and Zniber.

Al affects the total acidity of the soil. Thus, it influences the availability of nutrients, particularly phosphorus, in the soil. Some authors are currently evaluating the advisability of using the ratio of available P to exchangeable aluminum (Al) as an indicator of soil phosphorus saturation (Khiari et al., 2000).

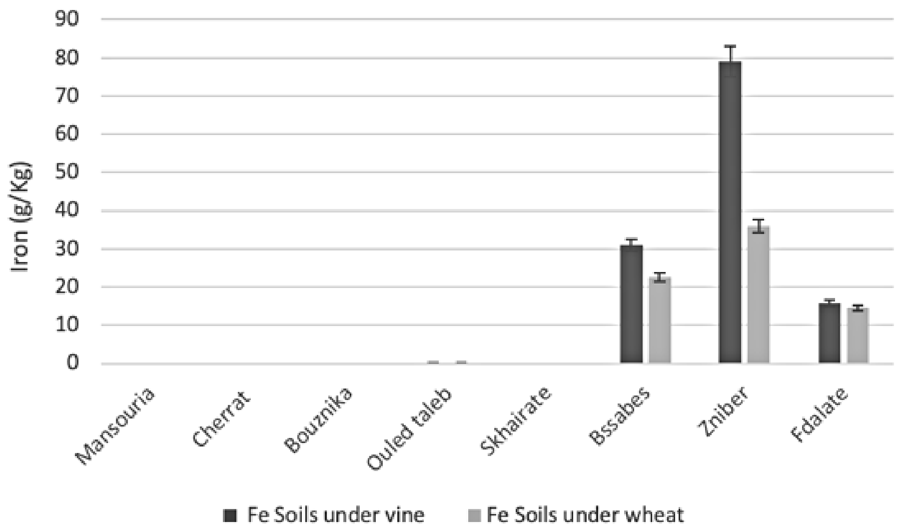

Figure 9. Al concentration in soils under the vine and the wheat on the studied sites

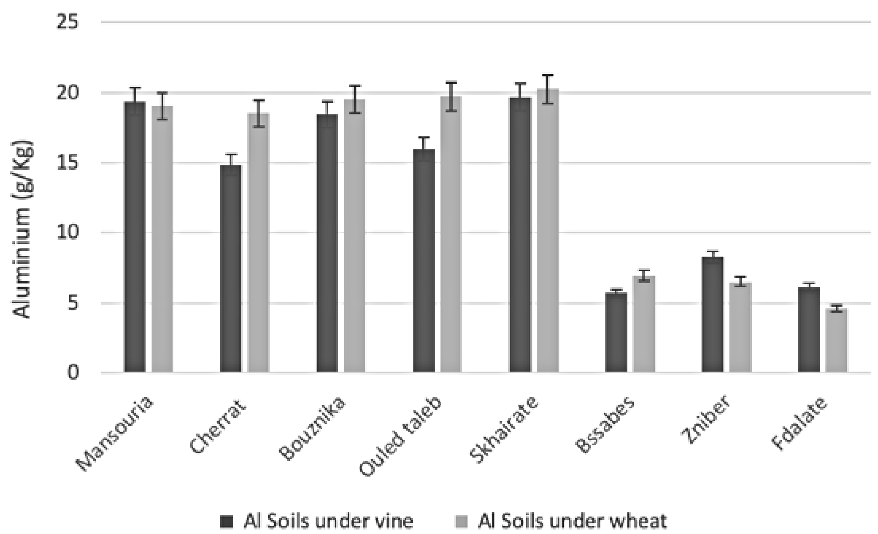

Figure 10. Fe concentration in soils under the vine and the wheat on the studied sites

The Fe contents of soils beneath neath vine and cereals are comparable in the stations of Mansouria (0.007 under vine and 0.008 g/kg under wheat), Cherrat (0.02 under vine and 0.03 g/kg under wheat), Bouznika (0.013 under vine and 0.01 g/kg under wheat), Ouled Taleb (0.065 under vine and 0.060 g/kg under wheat) and Skhairate (0.037 under vine and 0.024 g/kg under wheat), These levels are extremely low when compared to the WHO maximum average limits (0.01–0.05 g/kg). It was possible to detect iron deficiency in the soils at these stations using these data (Zaakour et al., 2018).

These levels increased in the stations of Bssabes (31.040 under vine and 22.489 g/kg under wheat), Zniber (79.011 under vine and 35.887 g/kg under wheat) and Fdalate (15.824 under vine and 14.619 g/kg under wheat), with a peak recorded under vine in the Zniber area (79.011 g/kg) (Figure 10).

Fe deficiency can be induced by the high pH value in the soil, during bad aeration, and/or by high zinc values (Cakmak et al.,1997; Rengel and Römheld 2000a; Crowley et al. 2002). The Fe deficiency at the investigated soil stations could explain the high Zn values. Several authors have considered cereal crops to be iron deficiency insensitive, which was the case in the examined soils (Cakmak et al., 1997, 1998; Kalayci et al., 1999; Rengel and Römheld, 2000).

The increase in iron at the last three stations was probably related to the presence of hidden iron-rich sulfide clusters. Gravimetric and magnetic studies have demonstrated the presence of an iron cap in the western part of the Mohammedia Ben Slimane area (Hathouti, 1990). This could explain the high iron concentrations recorded at the stations in the Bssabes, Fdalate, and the Zniber areas.

This iron accumulation could also be explained by the distribution of phosphorus concentration in soils, which constitutes a perfect layer of Fe, through the adsorption of P-PO4, whose affinity for Fe oxides and hydroxides is well known (Courchesne et al., 2002).

Cadmium (Cd) is one of the most ecotoxic metals that negatively affects soil biological activity, plant metabolism, ax well as human and animal health (Gülten, 2011). High Cd values were observed in wheat soil from the Zniber station and vineyard soils at both the Fdalate and Bssabes stations (Fig. 11). These values were higher than those recommended by the WHO (3 ppm). Low Cd concentrations were observed in Skhairate, Ouled Taleb, Bouznika, Cherrat, and Mansouria.

Because of its excessive affinity for the soil fertilizers (N, P, and K), OM, and $CaCO_3$, cadmium is less mobile at neutral to slightly acidic pH (Alloway, 1995; Joosse et al., 2003; Tremel-Schaub et al., 2005; Van & Jetten, 2006). This ought to provide an explanation for the excessive Cd concentration, which was most likely due to the Cd-rich manure and P fertilizers.

Martin-Garin et al. (2003), reported that Cd is adsorbed on calcite in the short term and, in the long term, diffuses into the carbonate crystal to form a solid solution of calcite, which may explain the frequent Cd enrichment found in the Fdalate, Bssabes, and Zniber soil stations.

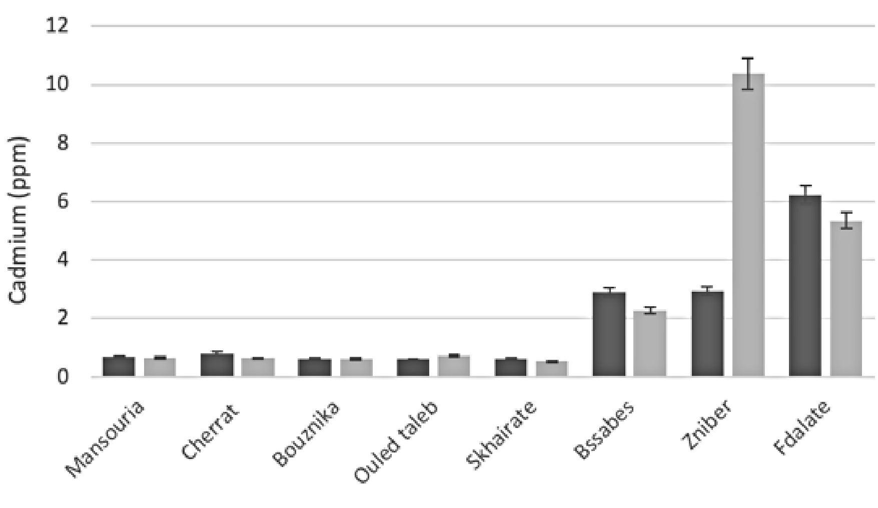

Figure 11. Cd concentration in soils under the vine and the wheat on the studied sites

The Cd content recorded in the soils under vines and wheat at the Mansouria, Cherrat, Bouznika, and Skhairate stations were comparable to those found at the Settat, Marrakech, Zeida, Ahouli, and Missouri stations and lower than the values reported by Matech et al. (2014) in Mediouna (Casablanca, Morocco), and by Tlemcani (2007) at the Mohammedia-Rabat soil stations (194.7 ppm).

Figure 12 presents the concentration of Cu in all stations, the Cu concentrations in the soils of the different study stations remain low and vary between a minimum of 1.14 ppm under vine and 1.43 ppm under wheat recorded at Fdalate and a maximum of 62.174 ppm under vine and 54.69 ppm under wheat noted at Ouled Taleb (66.7 ppm). These values are well below the limit of 100 ppm recommended by the WHO. The values recorded for Cu in the soils under wheat at the stations Zniber and Skhairate as well as under vines and under wheat at the stations Mansouria, Bouznika, Bssabes, and Fdalate were lower than the values reported in Mediouna (Casablanca), Marrakech, Settat, and Mohammedia-Rabat (Matech et al., 2014, Kennou et al., 2014, Kao et al., 2007, Tlemcani, 2007).

The results shown in Figure 13 show the Pb concentrations in any respect stations. The difference in Pb content between the grapevine and wheat fields was highly significant at all the stations.

At the Zniber station, the highest lead levels were found in vineyard soils (119.32 ppm). This exceeded the WHO standard cutoff value for uncontaminated soils (100 ppm). This concentration can be explained by its low mobility, which is

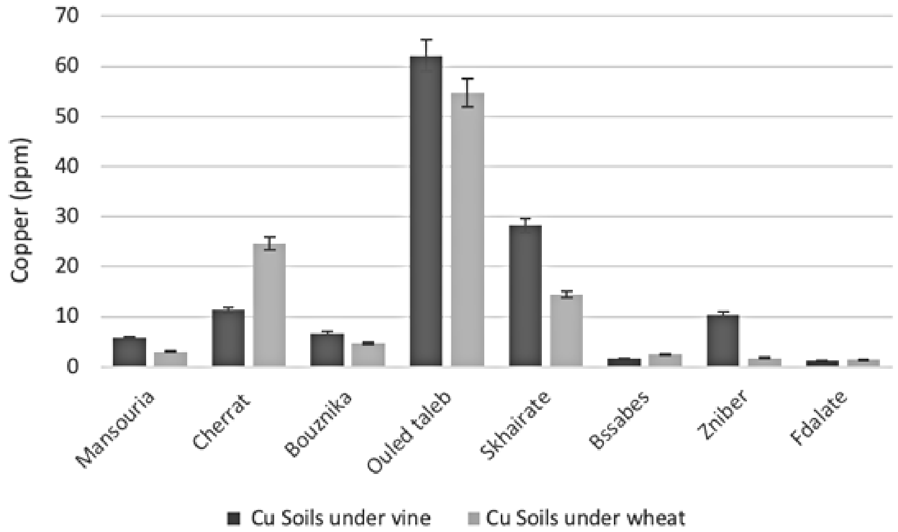

Figure 12. Cu concentration in soils under the vine and the wheat on the studied sites

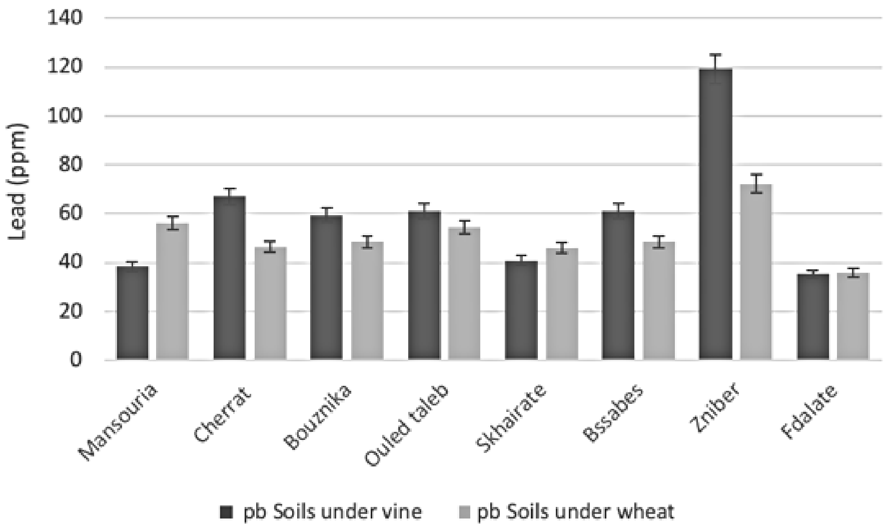

Figure 13. Pb concentration in soils under the vine and the wheat on the studied sites

principally associated with the clay and organic matter. However, Pb creates soluble organic compounds in the soil and exceeds its absorption level, it is considered mobile (Raskin and Ensley 2000; Kabata, 2000).

The concentrations of Pb in the soils under vines and wheat were higher than those obtained in Rabat, Sale, Kenitra, Settat, and Casablanca (El idrissi, 2009; Kao et al., 2007; Benazzouz et al., 2020).

Zinc (Zn) is an essential element in plants, animals, and humans. Zn deficiency reduces crop yield and crop quality production (Alloway, 2008).

The Zn concentrations at the eight stations are illustrated in Figure 14. The the present study, Zn content in soils under wheat and vine varied between 51.79–292.9 ppm. The maximum Zn contents were illustrated in the soils under vines Mansouria and Cherrat stations (451.01 ppm, 304.28 ppm, respectively) which are superior to the threshold recommended by the WHO standard (300 ppm). The high Zn content can be explained, on the one hand, by its solubility and mobility in comparison to other heavy metals, and on the other hand, by their high carbonate absorption.

Compared to the this study, the Mohammedia and Rabat soil samples showed a high Zn content at five stations (574–1134 ppm) because of the heterogeneous nature of household waste, which is the source of metal pollution (Kennou et al., 2014). In contrast, Matech et al., (2014), Kennou et al., (2014), Kao et al., (2007), and Tlemcani, (2007) reported lower Zn concentrations compared to the results obtained in thisstudy at Mansouria, Cherrat, Bouznika, Ouled Taleb, and Skhairate stations. A study conducted by Matech et al (2014) showed that four stations in the Mediouna region (Casablanca) had Zn concentrations lower than 100 ppm.

Pollution index

The impact of trace metal contamination on the ecosystem is linked to all contaminants, rather than just one metal, as various authors have agreed.

The last identified and recognized multi-element contamination is the outcome of an excessive increase in metal toxicity. Thus, the pollution index (PI) is the average percentage of metal concentration in soil samples relative to the bruit values (Jung, 1995).

The most significant PI values were detected at the Fdalate station (1.44 for grapevine soils and 0.68 for wheat growth), (1.09 for grapevine soils and 0.81 for wheat growth), and the Zniber station (2.20 for grapevine soils and 1.94 for cereals growing) in the Mohammedia and Benslimane regions (Zaakour et al., 2020).

The soils of these stations have high Cd concentrations of 19.3 ppm (Zniber area) and 15.6 ppm (Fdalate station), as well as high Pb concentrations of 182.3 ppm (Zniber area) and 46.7 ppm (Fdalate station) (Fig. 15). At all stations, is was discovered that the PI was higher in grapevine soils than in the areas under cereals growing. There was an apparent increase in the PI at the Zniber and Fdalate stations. The pedo-geo-chemical backdrop of these two stations, their proximity to the road, and treatment with phosphate fertilizers rich in Cd can explain these tendencies.

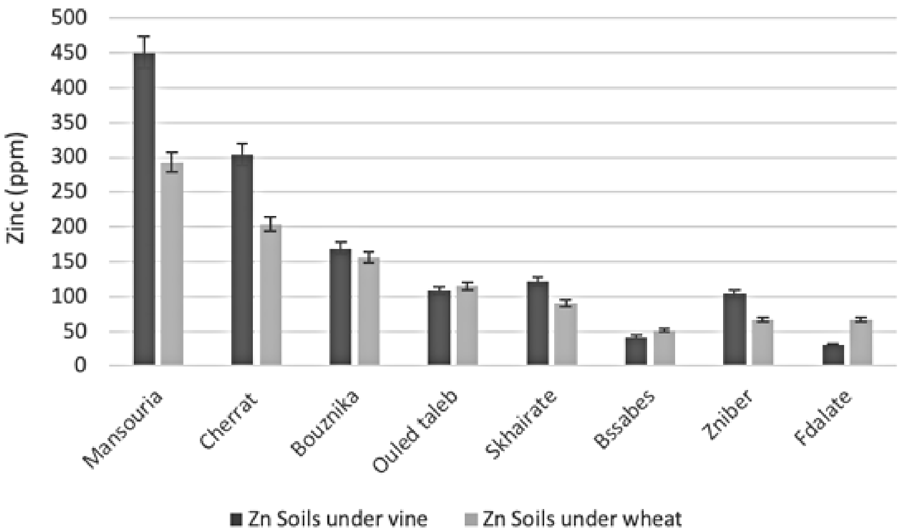

Figure 14. Concentration of zinc in soils under the vine and the wheat on the studied sites

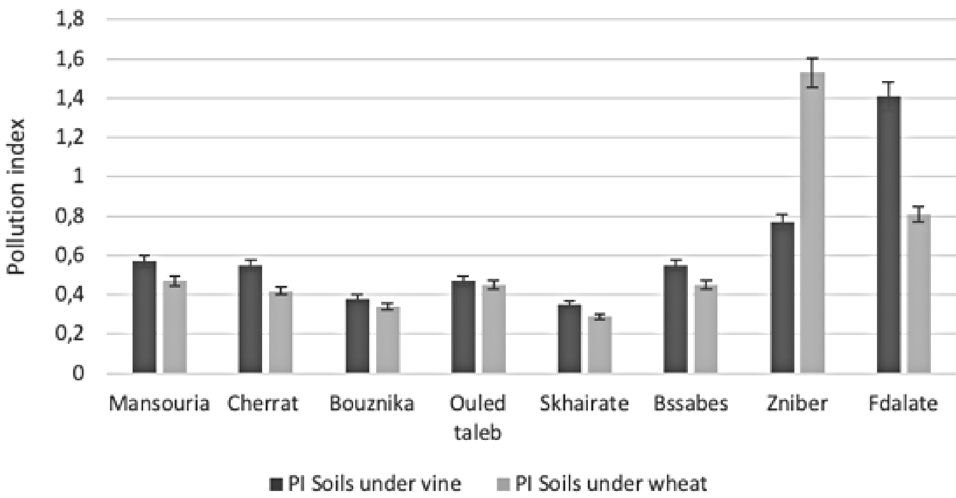

Figure 15. PI in soils under the vine and the wheat in each station

Compared with this study, the PI was higher than that observed at the Oued Merzeg station (PI = 1.5) (Benazzouz et al., 2020). In contrast, other studies have reported a variation between agricultural plots depending on the source of chemical pollution (Chemsi, 2014) or the impact of soil irrigation by wastewater (Matech et al., 2014; Siba et al., 2018).

Correlation test

The Pearson correlation coefficient can be used to measure the degree of correlation between the logarithms of the agronomic parameters and heavy metals.

The most studied heavy metals globally have a significant correlation with the threshold value α, which is equal to 0.05. Given the correlation between the different parameters studied, is can be emphasized that the correlations between pH, CE, and organic matter were positive. A significant correlation was also observed between the clay and Cd (-0.38), Cu (0.66), and Fe (0.40) (Table 1).

Thus, clay plays a significant role in determining the availability of heavy metals. Li et al (2000) showed that heavy metals can be absorbed and immobilized by clay minerals or complexed with soil organic matter, thus, forming organometallic complexes (Lamy, 2002). Calcium carbonates are the major constituents involved in heavy metal binding, either by adsorption, precipitation of hydroxides or carbonates, or insertion into $CaCO_3$ networks (Perrono, 1999). In the considered soils, highly significant correlations between $CaCO_3$ and Cd (0.5), Cu (-0.43), Fe (0.64), Zn (-0.47), and Al (-0.44). A high and moderate positive correlation was observed between Fe and Pb (0.68) and between Fe and $CaCO_3$ (0.64) respectively, indicating their possible common sources

Table 1. The correlation coefficients of our study

Variables	Cd	Cu	Fe	Pb	Zn	Al	Clays	Sand	Silt	OM	pH	$CaCo_3$
Cd	1											
Cu	-0.29	1										
Fe	0.37	-0.25	1									
Pb	0.11	0.063	0.68	1								
Zn	-0.34	-0.03	-0.29	-0.01	1							
Al	-0.19	0.108	-0.33	-0.20	0.158	1						
Clays	-0.38	0.667	-0.40	-0.11	0.307	0.198	1					
Sand	0.23	-0.79	0.134	-0.23	-0.17	-0.09	-0.71	1				
Silt	-0.07	0.659	0.067	0.376	0.05	0.012	0.34	-0.90	1			
OM	-0.18	0.11	-0.01	0.054	-0.20	0.215	0.082	0.018	-0.07	1		
pH	-0.12	0.46	-0.12	0.017	-0.18	0.228	0.037	0.004	-0.02	0.98	1	
$CaCo_3$	0.509	-0.43	0.644	0.167	-0.47	-0.44	-0.41	0.427	-0.31	-0.08	-0.26	1

from anthropogenic activities, as well as comparable behavior in the soil. In most soils, iron oxides are the preferred retention phases for many metals (Perrono, 1999). The negative correlations noted between Fe and Al (-0.33), Zn (-0.29), and clays (-0.44) showed that these hydroxides precipitated these elements within the soil. In addition, the average levels of organic matter in the studied soils may explain why Fe hydroxides are the main fixing phase of metals, especially since they are surface soil, so sulfides will be in an oxidized form that cannot trap the metals.

CONCLUSIONS

It may be concluded from the agronomic parameters of the examined soils, and it may be deduce that the pH and organic matter are higher in the soils under wheat growth than in those under vines. The total nitrogen rate was higher in wheat than in vines. This tendency can be partly affected by the residue type of agricultural contributions to the soil, and farm manure contributions can also influence it.

The stations Bssabes, Zniber, and Fdalate had the highest phosphorus and potassium concentrations. These concentrations are likely related to the use of ternary fertilizers (NPK) for vineyards soils and wheat.

The Shkairate, Ouled Taleb, Bouznika, Cherrat, and Mansouria stations had iron deficiency. In turn the stations of Fdalate, Zniber, and Bssabes recorded excessive anomalous concentrations, these concentrations are probably related to the proximity of an iron cap and/or sulfide cluster reported in the western part of the Mohammedia Ben Slimane area.

The iron content recorded in Mansouria, Bouznika, Cherrat, Ouled Taleb, and Skhairate were probably induced by the high zinc concentrations at these stations. In turn, the stations of Bssabes, Zniber, and Fdalate recorded excessive anomalous concentrations, these concentrations are probably related to the proximity of an iron cap and sulfide cluster reported in the western part of the Mohammedia Benslimane area.

The assessment of soil contamination under vineyards and wheat growth in the Mohammedia Benslimane region by the heavy metals Cd, Cu, Zn, and Pb demonstrates that the zone soils are at a greater level than uncontaminated soils.

Pollution levels differ based on the field and the contaminants involved. These contaminants are readily available in the soil and pose severe health concerns. Cadmium has several negative consequences on humans and the environment, including neurological, reproductive, and metabolic diseases.

The results obtained reveal a pollutant index that is extremely high at the stations of Fdalate and Zniber in comparison to other stations. At these two stations, the concentrations recorded for cadmium were probably related to the increased use of phosphate fertilizers rich in cadmium.

The correlation coefficients showed significant differences between the clays and Cd, Cu, and Fe. The correlation tests revealed high values for $CaCO_3$, Al, Cd, Cu, Fe, and Zn. This element tends to accumulate on the rich surface of the organic matter and clay layer.

REFERENCES

1. Adhikari K., Hartemink A.E. 2016. Linking soils to ecosystem services—a global review. Geoderma 262, 101111. AFNOR NF X31-107., 2003. Soil quality determination of the particle size distribution of soil particles: Pipette method. Theme: Physical properties of soils, Paris, France.
2. Alghobar M.A. et Suresha S. 2017. Evaluation of metal accumulation in soil and tomatoes irrigated with sewage water from Mysore city, Karnataka, India. Journal of the Saudi Society of Agricultural Sciences, 16, 49–59.
3. Alloway B.J.1995. Heavy metals in soils, In: Blackie academic and professional, 368.
4. Alloway B.J. 2008. Micronutrients and crop production: An introduction. In: Alloway B.J. (ed.). Micronutrient Deficiencies in Global Crop Production. Springer Science + Business Media, B.V., Dordrecht, 370.
5. Amami B., Serge D.M, Rhazi L., Rhazi M. et Bouahim, S. 2010. Modern pollen-vegetation relationships within a small Mediterranean temporary pool in western Morocco. Review of Palaeobotany and Palynology.
6. Badraoui M., Soudi B., Merzouk A., Farhat A. et M'hamdi A. 1998. Changes of soil qualities under irrigation in the Bahira region of Morocco: Salinization. Advances in GeoEcology.
7. Baize D. 1997. Total content of metallic trace elements in soils. INRA Editions. France, 410.
8. Benazzouz I., Talbi M., et Saber N. 2020. Environmental condition of soils in the Casablanca region. European Scientific Journal, 16(27), 1857–7881.
9. Bernard method described by Chamley. 1966. Guide

of the techniques of the laboratory of Marine Geology of Luminy, 198.

10. Bouabid A., Moustaoui D. 2005. Fertility and fertilization in fruit arboriculture in the Sais and the Middle Atlas (ENA of Meknès, Morocco), Conference proceedings: Environmental management of agriculture, 153–164.
11. Bouanan I., Bouarourou N. 2012. Diagnosis of soil and water quality in the Moulouya irrigated perimeter (Plain of Triffa). End of studies project presented for obtaining the diploma of Engineer in Agronomy, Option: Agro-Environment, Hassan II Institute of Agronomy and Veterinary Sciences, Rabat, Morocco, 111.
12. Brallier S., Harrison R.B., Henry C.L., Dongsen X. 1996. Liming effects on availability of Cd, Cu, Ni and Zn in a soil amended with sewage sludge 16 years previously. Water, Air and soil Pollution, 86, 195–206.
13. Cakmak I., Ekiz H., Yılmaz A., Torun B., Köleli N., Gültekin I., Alkan A. Eker S. 1997. Differential response of rye, triticale, bread and durum wheats to zinc deficiency in calcareous soils. Plant Soil, 188, 1–10.
14. Cakmak I., Torun B., Erenoglu B., Ozturk L., Marschner H., Kalayci M., Ekiz H. Yilmaz A. 1998. Morphological and physiological differences in the response of cereals to zinc deficiency. Euphytica, 100, 349–357.
15. Carranca C., Brunetto G., Tagliavini M. 2018. Nitrogen nutrition of fruit trees to reconcile productivity and environmental concerns. Plants, 7(1), 4.
16. Charlesworth S., Everett M., Mc Carthy, R., Ordonez A. Miguele E. 2003. Comparative study of heavy metal concentration and distribution in deposited street dusts in a large and small urban area: Birmingham and Coventry, West Midlands, UK. Environment International, 29, 563–573.
17. Chemsi Z. 2014. Effects of dust from the Bouskoura cement plant on the quality of neighboring agricultural soils (Casablanca, Morocco). PhD Thesis. Hassan II University of Casablanca, Faculty of Sciences Ben M'sik, Department of Geology.
18. Coll P. 2011. Quality of wine-growing soils in Languedoc-Roussillon: effects of agricultural practices. PhD Thesis. International Centre for Higher Studies in Agronomical Sciences fo Montpellier, Montpellier, France, 270.
19. Crowley M.M., Zhang F., Koleng J. Mcginity J. 2002. Stability of polyethylene oxide in matrix tablets prepared by hotmelt extrusion. Biomaterials, 23(21), 4241–4248.
20. Edahbi M., Khaddor M. Salmoun F. 2014. Characterization of the soils in North Morocco (Loukkos area), JMES 5(S1), 2028–2508.
21. El Idrissi. 2009. Characterization of some sites of pollution of pre-urban soils by metallic trace elements: Rabat-Kenitra Morocco), Postgraduate thesis for obtaining the diploma of Agronomist Engineer. Agronomic and Veterinary Institute Hassan II.
22. Faysse N. 2015. The rationale of the Green Morocco Plan: Missing links between goals and implementation. The Journal of North African Studies, 20(4), 622–634.
23. Gargouri K., Mhiri A. 2002. Relationship between soil fertility and phosphorus and potassium nutrition of the olive in Tunisia. Options méditerranéennes Series, A50, 199–204.
24. Ghanem H. 1978. Contribution to the study of Moroccan soils: genesis, classification and distribution of soils in the Zaërs regions and its borders: soils with a petroferric diagnostic horizon (post-fersiallitic pedogesis). The agronomic research notebooks. Editing. Inst. National Agronomic Research.
25. Gülten Yaylali A. 2011. Heavy metal contamination of surface soil around Gebze industrial area in Turkey. Journal homepage: www.elsevier.com/locate/microc.
26. Harmanescu M., Alda L.M., Bordean D.M., Gogoasa L. Gergen L. 2011. Heavy metals health risk assessment for population via consumption of vegetables grown in old mining area, a case study: Banat County, Romania. Chemistry Central Journal 5,64–73.
27. Hazrat A., Ezzat K. Ilahi I. 2019. Environmental Chemistry and Ecotoxicology of Hazardous Heavy Metals: Environmental Persistence, Toxicity, and Bioaccumulation. Journal of Chemistry.
28. Herrick E.J. 2000. Soil Quality: an indicator of sustainable land management? Applied Soil Ecology, 15(1), 75–83.
29. Hepsen Turkay F.S. 2010. Producing vermicompost by means of composting hazelnut and sewage sludge via earthworm and determining effests of vermicompost on the biological properties of soil in field and greenhouse experiment. PhD Thesis. Ondokuz Mayıs University, Department of Soil Science, Samsun, Turkey, 166.
30. Imperqto M., Adamo P., Naim D., Arienwo M., Stanzione D. Violante, P. 2003. Spatial distribution of heavy metals in urban soils of Naples city in Italy. Environmental Pollution, 124, 247–256.
31. Isnard H. 1951. Geographical study: The vine in Algeria. Ophrys, Gap, France.
32. ISO 11265. 1994. Soil quality: Determination of the specific electrical conductivity.
33. Jaishankar M., Tseten T., Anbalagan N., Mathew B.B. Beeregowda K.N. 2014. Toxicity, mechanism and health effects of some heavy metals. Interdiscip Toxicol, 7(2), 60–72.
34. Jiang B., Adebayo A., Jia J., Xing Y., Deng S., Guo

L., Liang Y. Zhang D. 2019. Impacts of heavy metals and soil properties at a Nigerian e-waste site on soil microbial community. Journal of hazardous materials, 362, 187–195.
35. Joosse P.J., McBride R.A. 2003. Assessing physical soil quality of plastic soils of differing mineralogy and pre-stress history using mechanical parameters: I. Saturated compression tests. Canadian Journal of Soil Science, 83, 45–63.
36. Jung M.C. 1995. Environmental contamination of heavy metals in soils, plans, waters and sediments in the vicinity of metalliferous mine in Korea. Unpublished PhD Thesis. University of London, 189–317.
37. Kabata P. 2000. Trace elements in soil and plants. CRC Press, Boca Raton, USA.
38. Kachenko A.G., Singh B. 2006. Heavy Metals Contamination in vegetables grown in urban and metal smelter contaminated sites in Australia. Water Air Soil Pollution, 169, 101–123.
39. Kalayci M., Torun B., Eker S., Aydin M., Ozturk L. Cakmak I. 1999. Grain yield, zinc efficiency and zinc concentration of wheat genotypes grown in a zinc-deficient calcareous soil in field and greenhouse. Field Crops Research, 63, 87–98.
40. Kao T., El Mejahed K., Bouzidi A. 2007. Evaluation of metal pollution in agricultural soils irrigated by wastewater in the city of Settat (Morocco), Bulletin of the Scientific Institute, Rabat, Life Sciences section, 29, 89–92.
41. Kennou B., Marie-Noëlle P., El Meray M., Romane A., Bodjona B. Arjouni Y. 2014. Assessment of heavy metal availability (Pb, Cu, Cr, Cd, Zn) and speciation in contaminated soils and sediment of discharge by Se, E3D Colloquium proceedings.
42. Khan F.U., Rahman A.U., Jan, A. Riaz M. 2004. Toxic and trace metals (Pb, Cd, Zn, Cu, Mn, Ni, Co and Cr) in dust, dustfall/soil. Journal of the Chemical Society of Pakistan, 26(4), 453–456.
43. Khan J.A., Usmani S.F., Khan S. 2012. Effect of fly ash on the mobility of amino acids through six typical soils of Aligarh district. JPBS, 15(5), 1–4.
44. Khan S., Rehman S., Khan A.Z., Khan M.A. Shah M.T. 2010. Soil and vegetables enrichment with heavy metals from geological sources in Gilgit, northern Pakistan. Ecotoxicology and Environmental Safety, 73, 1820–1827.
45. Khiari L., Parent, L.E., Pellerin, A., Alimi, A.R.A., Tremblay, C., Simard, R.R. & Fortin. J. 2000. An agri-environmental phosphorus saturation index for acid coarse-textured soils. Journal of Environmental Quality, 29, 1561–1567.
46. Kim N., Fergusson J. 1993. Concentrations and sources of cadmium, copper, lead and zinc in house dust in Christchurch, New Zealand. The Science of the Total Environment, 138, 1–21.
47. Komarniki J.K. 2005. Lead and cadmium in indoor air and the urban environment. Environmental Pollution, 136, 47–61.
48. Lakanen E., Ervio R. 1971. A comparison of eight extractants for the determination of plant available micronutrients in soil. Acta Agralia Fennica, 123, 223–232.
49. Lamy J., Ducaroir T., Sterckeman F. Douay T. 2002. Reactivity of organic materials. In: Metallic Elements in Soils Functional and Spatial Approaches, Baize, D., Tercé, M., (INRA-Editions), Paris, 269–282.
50. Lee C.G., Chon H.T. Jung M.C. 2001. Heavy metal contamination in the vincinity of the daduk Au-Ag-Pb-Zn mine in Korea. Applied Geochemistry, 16, 377–1386.
51. Li C., Frolking S. Butterbach Bahl K. 2005. Carbon sequestration in arable soils is likely to increase nitrous oxide emissions offsetting reductions in climate radiative forcing. Climatic Change, 72, 321–338.
52. Li X., Shen Z., Wai O.W.H., Li Y.S. 2001. Chemical forms of Pb, Zn and Cu in the sediment profiles of the Pearl River Estuary. Marine Pollution Bulletin, 42(3), 215–223.
53. Liu G.N., Wang J., Zhan E.X., Hou J. Liu X.H. 2016. Heavy metal speciation and risk assessment in dry land and paddy soils near mining areas at Southern China. Environmental Science and Pollution Research, 23(9), 8709–8720.
54. Manta D.S., Angelone M., Bellanca A., Neri R. Sprovieri M. 2002. Heavy metal in urban soils: a case study from the city of Palermo (Sicily), Italy. Science of the Total Environment, 300(1–3), 229–243.
55. Martin-Garin A., Van Cappellen P. Charlet L. 2003. Aqueous cadmium uptake by calcite: A stirred flow-through reactor study. Geochimica & Cosmochimica Acta, 67(15), 2763–2774.
56. Matech F., Zaakour F., Chemsi Z., Moustarhfer K., Mohcine H., Marrakchi C. Saber N. 2014. Effect Of Concentration Increasing Of Cd, Cr, Cu, Pb And Zn In Soils Irrigated By Waste Waters Of Hassar River (Region Of Mediouna-Casablanca- Morocco). Physical and Chemical News, 71, 94–99.
57. Mc Lean E.O. 1982. pH and lime requirements. In: Page, A.L. et al. (Ed.), Methods of Soil Analysis, Part 2, second ed., Agronomy, Soil Society of America, Madison, WI, 9, 199–244.
58. Koch A., McBratney A., Adams M., Field D., Hill R., Crawford J., Minasny B., Lal R., Abbott L., O'Donnell A., Angers D., Baldock J., Barbier E., Binkley D., Parton W., Wall D.H., Bird M., Bouma J., Chenu C., Flora C.B., Goulding K., Grunwald S., Hempel J., Jastrow J., Lehmann J., Lorenz K., Morgan C.L., Rice C.W., Whitehead D., Young I., Zimmermann M. 2013. Soil security: solving the global soil crisis. Global Policy, 4, 434–441.

59. Michaud A.M., Bravin M.N., Galleguillos M., Hinsinger P. 2007. Copper uptake and phytotoxicity as assessed in situ for durum wheat cultivated in Cu-contaminated, former vineyard soils. Plant Soil, 298, 99–111.
60. Moughli L., Cherkaoui F.Z. 2005. Rational mineral fertilization of crops and development of eco-advice sheets: Case of sugar beet, Environmental management of agriculture. Proceedings Editions, 141–152.
61. Muhammad S., Shah M.T., Khan S. 2011. Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, Northern Akistan. MicroChemical Journal, 98, 334–343.
62. Nagajyoti P.C., Lee K.D. Sreekanth T.V.M. 2010. Heavy metals, occurrence and toxicity for plants: A review. Environmental Chemistry Letters, 8, 199–216.
63. Oberholzer H.-R., Freiermuth Knuchel R., Weisskopf P., Gaillard G. 2012. A novel method for soil quality in life cycle assessment using several soil indicators. Gron. Sustain Dev, 32(3), 639–649.
64. Ocio J.A., Brookers P.C. Jenkinson D.S. 1991. Field incorporation of straw and its effects on soil microbial biomass and soil inorganic N. Soil Biology and Biochemistry, 23, 171–176.
65. Oldfield E.E., Wood S.A. Bradford M.A. 2018. Direct effects of soil organic matter on productivity mirror those observed with organic amendments. Plant Soil, 423, 363–373.
66. Olsen S.R., Cole C.V., Watanabe F.S. Dean, L.A. 1954. Estimation of available phosphorous in soils by extraction with sodium bicarbonate, In: Soils-Phosphorus content. Washington, U.S. Dept of Agriculture, 939, 1–19.
67. Perrono P. 1999. The metal micropollutants of sludge from urban sewage treatment plants and agricultural spreading. Mém. D.U.E.S.S., D.E.P., University of Picardie, Amiens, 100.
68. Radwan M.A., Salama A.K. 2006. Market basket survey for some heavy metals in Egyptian fruits and vegetables. Food and Chemical Toxicology, 44(8), 1273–1278.
69. Rahman M.A., Rahman M.M., Reichman S.M., Lim R.P. Naidu, R. 2014. Heavy metals in Australian grown and imported rice and vegetables on sale in Australia, Health hazard. Ecotoxicology and Environmental Safety, 100, 53–60.
70. Raskin I., Ensley B.D. 2000. Phytoremediation of toxic metals: Using plants to clean up the environment. John Wiley, New York, 304.
71. Rengel Z., Römheld V. 2000. Root exudation and Fe uptake and transport in wheat genotypes differing in tolerance to zinc deficiency. Plant and soil, 222, 25–34.
72. Rengel Z., Römheld V. 2000a. Differential tolerance to Fe and Zn deficiencies in wheat germplasm. Euphytia, 113, 219–225.
73. Romheld V., Marschner H. 1990. Genotypical differences among graminaceous species in release of phytosiderophores and uptake of iron phytosiderophores. Plant and Soil, 123, 147–153.
74. Siba A., El Jaafari S., Mokhtari F. 2018. Bacterial and toxic pollution of industrial and domestic wastewater on the Atlantic coast (Casablanca-East-Morocco). European scientific Journal, 14, 425–431.
75. Tlemcani A. 2007. ETM content (Cd, Cu, Cr, Pb and Zn) in soils in the Mohammedia-Rabat region. DESA thesis, Faculty of Sciences of Rabat, Mohammed V University, Morocco, 70.
76. Trégoat O., van Leeuwen C., Choné X. Gaudillère J.P. 2002. The assessment of vine water and nitrogen uptake by means of physiological indicators. Influence on vine development and berry potential. International Journal of Vine and Wine Sciences, 36(3), 133–142.
77. Tremel-Schaub A., Feix I. 2005. Soil contamination, Transfers of Soils to plants, EDP Sciences and ADEMEeditions.
78. Van der Perk M., Jetten V.G. 2006. The use of a simple sediment budget model to estimate long-term contaminant export from small catchments. Geomorphology, 79, 3–12.
79. Walkley A., Black I.A. 1934. An examination of the Degtjareff method for determining organic carbon in soils: Effect of variations in digestion conditions and of inorganic soil constituents. Soil Science, 63, 251–263.
80. Yaakoubi A. 2010. Biotransformation of vegetable waters by biological means and impact of their spreading on soil quality and agricultural productivity: Case of the vine, region of Meknes, PhD Thesis. Faculty of Sciences of Meknes, Moulay Ismail University, Morocco.
81. Yan X., Liu M., Zhong J., Guo J., Wu W. 2018. How Human Activities Affect Heavy Metal Contamination of Soil and Sediment in a Long-Term Reclaimed Area of the Liaohe River Delta, North China. Sustainability, 10, 338.
82. Zaakour F. Saber N. 2018. Assessment of Environnemental Quality in Soil under Wheat and Vines in Mohammedia-Benslimane region of Morocco. LAP LAMBERT Academic Publishing.
83. Zaakour F., Saber N., Ismaili Alaoui D., Ben Hachmi M.K. 2020. The environnemental quality of soil under wheat and vines in the region of Mohammadia Benslimane (Morocco), E3S Web of Conferences, 150, 03 005.