ASSESSMENT OF METAL TRACE ELEMENT CONTAMINATION OF SURFACE SOILS BY ROAD TRAFFIC (RABAT-SALE HIGHWAY - MOROCCO)

*Balambula Grace  
Laboratory of applied geology, Geomatics and Environment,  
Faculty of Sciences Ben M'Sik, University Hassan II, Casablanca, Morocco

Baghdad Bouamar  
Department of Natural Resources and Environment,  
Hassan II Agronomy and Veterinary Institute, Rabat, Morocco

El Hadi Hassan  
Laboratory of applied geology, Geomatics and Environment,  
Faculty of Sciences Ben M'Sik, University Hassan II, Casablanca, Morocco

Laghlimi Mariem  
Department of Natural Resources and Environment,  
Hassan II Agronomy and Veterinary Institute, Rabat, Morocco  
*Corresponding author

ABSTRACT

The vehicle emissions cause dangerous metal rejections for environment. Roadside soils can act as long-term reserves of non-biodegradable metals. The overall objective of this research is to study the impact of the metals emitted by vehicles on the roadside soils close to Rabat-Sale high-way and their spatial distribution. This study evaluated the concentration of metal trace element (MTE) in the soils, analyzed the correlation between these metals and land use, as well as with physico-chemical parameters.

Samples of roadside soils were collected at precise distances (5, 50 and 100 m), moving away from the road, to analyze spatial distribution of MTE in the soils. The averages of concentrations found in the roadside soils close to Rabat-Sale highway are slightly high, but show an enrichment in some stations.

The traffic characteristics are one of the parameters to be considered in the evaluation of the im-pact of the road traffic on the surrounding soils. The age of the
highway plays a very important part in the metal enrichment of soil. In fact, Rabat-Sale highway of recent age presents an enrichment in elements Mn, Co; elements lately integrated in the field of road traffic. The concentrations of metals recently introduced into automobile technology are higher in the young roads, whereas metals which have been used for several years (Cd, Cu, Pb, Zn) would be higher in the roads of advanced age, confirming the risk of metal deposit in the roadside soils. Significant correlations were found between the concentrations of MTE in the soil.

Keywords: highway; pollution; MTE; soil; Rabat-Sale; Morocco


1. INTRODUCTION

Environmental pollution by metal trace elements (MTE) coming from the cars is a current topic. Indeed, the development process is inevitable because countries follow global development and the growth of human population. With the speed of urbanization and industrialization, transport has become one of the significant problems for the environment. Road traffic is a primary source of metal contamination for urban and road soils (Werkenthin et al., 2014). Many studies on the pollution of roadside soils were undertaken these last years (Akbar et al., 2006; Aktas and Kocabas, 2010; Werkenthin and Wessolek 2014), among others. It is well established that industrial activities are generally the main factors of air pollution (Jerrett et al., 2005; Zhang et al., 2010). However, there is a decreasing trend of atmospheric pollution emissions coming from factories; road traffic is currently regarded as the main source of contaminants (González et al., 1996). With fast development, the intensive anthropogenic activities have led to an emission in great quantity of pollutants in urban environment. These pollutants have aroused great concern in environmental studies, because of their persistence (Mwesigye et al., 2016; Peng et al., 2017).

Many studies showed the contribution of traffic in the emission of metal traces elements in environment, in particular in roadside soils (Wang et al., 2009, Atkinson et al., 2011; Yang et al., 2011; Ordóñez et al., 2015; Botsou et al., 2016). Therefore, it is very important to explore the accumulation of MTE in roadside soils. During the last years, many researchers have carried out research on MTE in roadside soils in various countries, for example in Greece (Christoforidis and Stamatís, 2009), Saudi Arabia (Kadi, 2009), Germany (Kluge and Wessolek, 2012), Canada (Wiseman et al., 2015), Australia (De Silva et al., 2016) and Spain (Ordóñez et al., 2015). The MTE generated by road activities could extend from 100 to 200 m on the two sides of the roads (Dan Badjo, 2008; Zhang et al., 2015), the majority remaining in the surface soil (Boivin et al., 2008).

Former researches on metal trace elements in road soils are relatively limited because they are mainly focused on conventional metals of the road traffic: Cd, Cu, Pb, Zn and Cr. Indeed, few works could be mentioned on the new metals introduced into automobile technology during the last decades, like Sb in brake pads (Hjortenkrans et al., 2007), the element of group Pt in the vehicle, catalysts of emission to reduce air pollution (Almécija et al., 2015) and Mn in the fuel, in the place of Pb (De Silva et al., 2016). The latter will be approached in this work. Pollutants are emitted by various parts of vehicles and road materials (Legret and Pagotto 2006). As an indication, the tires and the combustion of fuels release Cadmium (Zhang et al.
Assessment of Metal Trace Element Contamination of Surface Soils by Road Traffic (Rabat-Sale Highway - Morocco)

2015); zinc is emitted by lubricating oils and the abrasion of tires (Smolders and Degryse 2002); copper can come from brake linings and tires (Hjortenkrans, et al., 2007). Lead, forbidden since 1/1/2000 in Morocco, is emitted by the fuels with lead (Van Bohemen and Van de Laak 2003); while chromium is released by the abrasion of tires and brake pads, as well as oil residues (Zehetner et al., 2009). Some MTE such as Manganese, Molybdenum and Arsenic will be approached in this work (Table 2). Most of the time, metal trace elements coming from the road traffic are suspended in the atmosphere in the form of dust. They can be deposited in the soils by rainwater. These heavy metals can be unequally distributed in space because of many factors, such as wind, precipitations, type and intensity of the traffic, state of the road and types of land use (Liu et al., 2016). Once the contents of heavy metals are determined at the laboratory, the contamination of the soil in MTE can then be measured. The present study aims to determine the various factors that influence studied soil contamination depending on the land use of each station and to evaluate the contamination degree of the roadside soils close to Rabat-Sale highway using geostatistical analyses methods. The soils analyzed were collected until 150m on both sides of the highway on 20 cm of depth.

2. MATERIAL AND METHODS

2.1 Description of the studied area

Rabat-Sale highway is located in the North-West of Morocco between the latitude 33°58' and 33°55' N and longitude 6°48' and 6°44' O (Figure 1). It belongs to the field of the Moroccan Meseta. The course of the layout of the highway is extremely varied. It comprises peri-urban areas, cultivated grounds or without real farming value, as well as small islets of natural space. The area belongs to the field of coastal Meseta, framed by the atlasic and Rifian chains. It is defined by the tabular mode of secondary deposits on primary formations strongly folded by Hercynian orogenesis. The climate is subtropical with a strong oceanographical influence. However, the area remains semi-arid moderate by the oceanic influence.

![Figure 1 Location of Rabat-Sale highway.](http://www.iaeme.com/IJCIET/index.asp)
2.2. Soil sampling

Seven sites of sampling (S1-S7) along the highway were selected in July 2017. The soils were taken at 5, 50 and 100 m at the edge of both sides of the highway, on each site (Figure 2). GPS was used to record the coordinates of the sampling sites. We used an auger to take 1000g of soil to 20 cm of depth on each of the 7 sites of sampling. A total of 42 samples was taken. The samples of soil were stored in plastic bags for transport to the laboratory (Faculty of Science - Ben M’sik) where they were dried, crushed and filtered. They were then divided into two parts, one for agronomic analyses at the Hassan II Agronomy and Veterinary Institute in Rabat and the other for environmental analyses at the Veritas laboratory of analyses (Canada) by Inductively Coupled Plasma Mass Spectrometry methods (ICP-MS). Cartography of the land use in the studied area around the highway as that of the distribution of the MTE is carried out, using the ArcGis software with the aim of studying, discriminating and highlighting the contribution of the motorway traffic in the soil, knowing that some studied elements are not directly associated with the latter.

2.3. Methods of analysis

For the agronomic analysis of the soil, we measured the pH by the potentiometric method (the soil-water ratio is of 1/2.5), electric conductivity with a conductimeter in a paste saturated with soil 1/5 (USSL, 1954), the organic matter of the soil by the Walkley-Black method (1934) and Olsen and al., (1954), as well as the content calcium carbonate measured through De Bernard calcimeter. The environmental analysis is based on the evaluation of the total content of MTE by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). The soils were digested with concentrated acid solutions HNO3-HClO4-HF smoking and taken dry. The residue is dissolved in HCl. Data were analyzed using XLSTAT software. A cartography of the distribution of MTE in the soil was used to analyze the distribution of pollutants and to place a limit of impact. The Pearson test of correlation was used to evaluate affinity between MTE and physico-chemical parameters (pH, EC, MO, CaCO3). The Principal components Analysis (PCA) was used to identify the potential sources of metals.

![Figure 2](http://www.iaeme.com/IJCIET/index.asp) Location of the sampling points along the Rabat-Sale highway.
3. RESULTS AND DISCUSSION

The concentrations in MTE in the soils along the highway are presented in Table 1. The average concentrations of analyzed elements in the soil are ordered as follows: Mn > Cr > Zn > Ni > Pb > Cu > As > Co > Mo > Cd. In general, the average concentrations of metal traces are significantly higher than the values of concentrations of ordinary soils suggested by Baize (1997). We observed in station 1 values of concentration in Pb, Cd, Cu, Ni and Zn higher than those of ordinary soils. In station 6, we also notice particularly high concentrations in Cr and Zn. These different enrichments can be explained by the fact that station 1 is at the crossing between the A1 and A3 motorway, especially that these elements are underlined in former works on pollution in the road field (Wei and Yang, 2010; Feng et al. 2012; Saeedi et al. 2009). Enrichment would then be more important compared to other stations and at the level of this station, where we find several factories (treatment of wood and aluminum; manufacturing of industrial gas) and building sites. For station 6, enrichment can have as a source, not counting the contribution of the road traffic, the landfills of Oum Azza and the restored landfills of Akrech, which are very close to this station (Figure 3). Table 1 Statistical parameters of MTE concentrations in the studied soils.

<table>
<thead>
<tr>
<th>variable</th>
<th>Minimum</th>
<th>Mean</th>
<th>Maximum</th>
<th>Standard deviation</th>
<th>Median</th>
<th>control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mo</td>
<td>0.05</td>
<td>0.566</td>
<td>4.14</td>
<td>0.666</td>
<td>0.38</td>
<td>0.74</td>
</tr>
<tr>
<td>Cu</td>
<td>9</td>
<td>13.383</td>
<td>39.7</td>
<td>6.613</td>
<td>12.75</td>
<td>2.58</td>
</tr>
<tr>
<td>Pb</td>
<td>6.36</td>
<td>16.351</td>
<td>98.5</td>
<td>14.52</td>
<td>11.64</td>
<td>5.23</td>
</tr>
<tr>
<td>Zn</td>
<td>11.9</td>
<td>36.126</td>
<td>114.2</td>
<td>24.05</td>
<td>27.75</td>
<td>28.35</td>
</tr>
<tr>
<td>Ni</td>
<td>3.5</td>
<td>16.647</td>
<td>62.6</td>
<td>12.66</td>
<td>11.55</td>
<td>3.68</td>
</tr>
<tr>
<td>Co</td>
<td>2.1</td>
<td>9.383</td>
<td>53.8</td>
<td>8.323</td>
<td>8.2</td>
<td>1.52</td>
</tr>
<tr>
<td>Mn</td>
<td>141</td>
<td>536.69</td>
<td>2389</td>
<td>386.4</td>
<td>449.5</td>
<td>62.2</td>
</tr>
<tr>
<td>As</td>
<td>0.7</td>
<td>11.414</td>
<td>47.2</td>
<td>10.38</td>
<td>6.95</td>
<td>19</td>
</tr>
<tr>
<td>Cd</td>
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<td>0.073</td>
<td>0.66</td>
<td>0.112</td>
<td>0.03</td>
<td>0.35</td>
</tr>
<tr>
<td>Cr</td>
<td>19</td>
<td>42.904</td>
<td>98</td>
<td>18.178</td>
<td>40</td>
<td>32.16</td>
</tr>
</tbody>
</table>

[1] Natural levels in the earth's crust (Bowen, 1979)
[2] Average levels in the continental crust (Wedepohl, 1995)

The strong presence of agricultural soils in the close vicinity of the highway could be the possible source of enrichment of certain elements (Figure 4). The concentration of As in the soil is often related to the contribution of fertilizers in various farming practices, this could explain the concentration which would not be directly related to the road traffic. This approach is also confirmed by the study of the PCA (Table 3). As does not present a significant correlation with the other analyzed elements recognized in road field pollution such as Pb, Zn and Cu. However, few studies reported on the concentration in As in the roadside soils in spite of its emission during the brake wear and in the fuel (Table 2). Thus, the road traffic can emit small amounts of short-term As, without considerable concentration in the long-term and this for all the vehicles (Ozaki and al., 2004). Petrol contains 0.03-0.12 mg/kg of As (Nakamoto, 2000). Some values reported for the As, starting from the roadside soil, are of 14.7 mg/kg Jeddah City, Saudi Arabia, (Kadi, 2009), 7.33 Mg/kg of Xuzhou, China (Ozaki and al., 2004) and 6 mg/kg with Dubai, Water (Aslam and al., 2013). In comparison with this study, concentrations of As in stations 3.6, and 7 are 32.5; 35.3; 47.2 mg/kg.
Figure 3 Land use along the Rabat-sale highway.

Although in small quantity, the analysis of Pb concentration in the soil proves that there still exists today a concentration in this element coming from the road traffic. Lead is emitted by various sources such as fuel (tetrathyl lead), brake wear, engine oil, bearings, pneumatic wears and abrasions of the road (Aslam and al., 2011, Lee and Touray, 1998, Lough and al., 2005). The Pb emission of the vehicles has decreased these last years. In agreement with that, the concentrations of Pb recorded are low for the roads which were built after 2000, i.e. after the ban of the use of lead in petrol. Today, instead of Pb, a Manganese compound called MT (Methylcyclopentadienyl manganese tricarbonyl) is used as an additive for petrol. The strongest Mn concentration was recorded on the soils of station 1, (2389 mg/kg) roads with strong traffic because of the crossing with A1 and A3 motorway.

Table 2 Sources of emission of the vehicles and associated metal contamination (Araratyan and Zakharyan, 1988; Davis and al., 2001; Folkeson, 2005; Garcia-Miragaya and al., 1981; Gjessing and al., 1984; Li and al., 2001; Lindgren, 1996; Luhana and al., 2004; von Uexküll and al., 2005; Winther and Slento, 2010).

<table>
<thead>
<tr>
<th>Sources</th>
<th>Metal</th>
</tr>
</thead>
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<tr>
<td></td>
<td>As</td>
</tr>
<tr>
<td>brake wear</td>
<td>X</td>
</tr>
<tr>
<td>Tire wear</td>
<td>X</td>
</tr>
<tr>
<td>Abrasion of the road</td>
<td>X</td>
</tr>
<tr>
<td>Exhaust Catalyst</td>
<td></td>
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<tr>
<td>fuel</td>
<td>X</td>
</tr>
</tbody>
</table>

Recent studies support that the accumulation of Mn in the roadside soils is strongly correlated with the age of the roads (De Silva and al., 2016). A similar relation was shown by Cohen and al. (2005) for the traffic density and the concentration of Mn in the air. The highest
concentration of Zn is 114.2 mg/kg, recorded in station 1 and this is alarming with regard to
the contamination of Zn in the roadside. In addition to the brake wear, Zn is mainly emitted
following tires wear in the vehicles (Hjortenkrans and al., 2007, Li and al., 2004). Zinc is added
to tires during the production like ZnO. The concentrations of zinc in the soil, ranging between
70 to 400 mg/kg or more, are considered as toxic (Alloway and al., 1990). The analysis of
the land use map at the edge of the highway, going up to 3 km on each side, supports the theory
that the high concentrations found in station 6 would be related to the presence of the landfill,
far beyond the impact of the road traffic. Spatial distribution cards clearly show the
characteristics of distribution of heavy metals in the soil on both sides of the highway, and road
traffic’s influence on the content of heavy metals on both sides of the soil (Figure 3). The
concentrations of the majority of metals are not strongly affected by the physico-chemical
properties of the soil (Table 3), indicating that metal concentrations are controlled by
anthropogenic contamination sources (Mao and al., 2014). In comparison with a recent study
carried out in Australia (De Silva and al., 2016), the strongest Mn concentrations were recorded
on the new roads with strong traffic because of the replacement of Pb by Mn in petrol. Pb
concentrations are found in old roads with strong traffic, Cu and Zn concentrations come from
moderately old roads with average traffic; Cd, Mo and Ni concentrations come from old roads
with low traffic. The metals recently introduced in the study of the impact of the road traffic in
the soil such as Mn, Sb and Pd tend to be very concentrated in the medium old roads, while
metals persisting in the emissions of vehicles such as Cr, Pb and Zn are higher in the roads of
older age. This could explain the fact that except for station 1, which is located at the crossing
of old motorways, concentrations in MTE is not very high in the analyzed soil because the
motorway is of recent age. Metals such as Co and Mo are in the field of road traffic (Table 2),
but they have often received less attention in the studies of roadside soils (Although these
metals have low emissions, they are important because new methods in the technology
of motor vehicles can lead to an increase in the emissions of these elements in the future emissions of
vehicles).

**Table 3** Pearson coefficients of correlation of the concentrations in MTE.

<table>
<thead>
<tr>
<th>Variables</th>
<th>pH</th>
<th>CE</th>
<th>MO</th>
<th>CaCO3</th>
<th>Zn</th>
<th>Pb</th>
<th>Mo</th>
<th>Mn</th>
<th>Cu</th>
<th>Co</th>
<th>As</th>
<th>Cd</th>
<th>Ni</th>
<th>Cr</th>
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<td>1</td>
<td>1</td>
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<td>1</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>CE</td>
<td>-0.316</td>
<td>1</td>
<td>0.583</td>
<td>1</td>
<td>0.741</td>
<td>-0.424</td>
<td>0.532</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>MO</td>
<td>0.603</td>
<td>-0.583</td>
<td>1</td>
<td>0.732</td>
<td>-0.733</td>
<td>-0.733</td>
<td>0.732</td>
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<tr>
<td>CaCO3</td>
<td>0.741</td>
<td>-0.424</td>
<td>0.532</td>
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<td>0.731</td>
<td>0.625</td>
<td>-0.600</td>
<td>-0.330</td>
<td>1</td>
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</tr>
<tr>
<td>Zn</td>
<td>-0.319</td>
<td>0.625</td>
<td>-0.600</td>
<td>-0.330</td>
<td>1</td>
<td>0.731</td>
<td>0.625</td>
<td>-0.600</td>
<td>-0.330</td>
<td>1</td>
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<tr>
<td>Pb</td>
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<td>0.565</td>
<td>-0.692</td>
<td>-0.500</td>
<td>0.844</td>
<td>1</td>
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<tr>
<td>Mo</td>
<td>-0.732</td>
<td>0.439</td>
<td>-0.733</td>
<td>-0.664</td>
<td>0.778</td>
<td>0.946</td>
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<tr>
<td>Mn</td>
<td>-0.895</td>
<td>0.515</td>
<td>-0.727</td>
<td>-0.834</td>
<td>0.572</td>
<td>0.859</td>
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<tr>
<td>Cu</td>
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<td>-0.749</td>
<td>-0.765</td>
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<tr>
<td>Co</td>
<td>-0.921</td>
<td>0.542</td>
<td>-0.709</td>
<td>-0.732</td>
<td>0.623</td>
<td>0.912</td>
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<tr>
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<td>0.186</td>
<td>-0.523</td>
<td>0.389</td>
<td>0.516</td>
<td>0.357</td>
<td>0.239</td>
<td>-0.018</td>
<td>0.179</td>
<td>0.083</td>
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<tr>
<td>Cd</td>
<td>0.131</td>
<td>-0.362</td>
<td>0.001</td>
<td>-0.102</td>
<td>0.379</td>
<td>0.215</td>
<td>0.395</td>
<td>0.099</td>
<td>0.338</td>
<td>0.014</td>
<td>0.115</td>
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<tr>
<td>Ni</td>
<td>-0.804</td>
<td>0.355</td>
<td>-0.618</td>
<td>-0.555</td>
<td>0.594</td>
<td>0.923</td>
<td>0.930</td>
<td>0.910</td>
<td>0.781</td>
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<td>0.209</td>
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<tr>
<td>Cr</td>
<td>-0.829</td>
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<td>-0.845</td>
<td>-0.477</td>
<td>0.323</td>
<td>0.646</td>
<td>0.621</td>
<td>0.745</td>
<td>0.545</td>
<td>0.789</td>
<td>0.346</td>
<td>-0.330</td>
<td>0.686</td>
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</tbody>
</table>

The significance of Pearson coefficients of correlation between Cu, Pb, Ni and Zn suggests
that these metals come from a common source, probably brakes wear. In addition to brakes
wear, Zn just like Pb is emitted following tires wear in the vehicles (Hjortenkrans and al., 2007,
Li and al., 2004). The concentrations of zinc in the soil, ranging between 70 to 400 mg/kg or
more, are regarded as toxic (Alloway and al., 1990). Although Co is not an element generally treated in the various studies on the impact of road traffic in the surrounding soils, its positive and largely significant correlation with Zn, Pb, Mo and Cu (0.623; 0.912; 0.907;0.860) suggests a common source which would be the road traffic. This correlation should be taken into account in the next studies. The indices of correlation for As and Cd are slightly significant, which can be explained by the fact that As is not an element emitted during road traffics and that for Cd, the age of the road plays a key role in its enrichment.

4. STUDY OF THE SPATIAL DISTRIBUTION OF MTE IN THE SOILS CLOSE TO THE HIGHWAY

The spatial distribution of some MTE in the soils can reflect the extent of contamination and the type of human activities specific to the pollution of environment, for example industrial emissions, traffic activities etc… (Yu et al., 2016; Foti and al., 2017; Yang and al., 2017). From the surroundings while moving away from the motorway, the variations of spatial distribution of the analyzed MTE are significant (Figure 4). This distribution is compared with the value of the local pedological background (testing soil) (table1). The analysis of isotonic maps of the studied elements confirms the theory that in the presence of road pollution, concentrations in MTE decrease while moving away from the road. Nevertheless, not all the analyzed metals show a normal distribution with reduction in content while moving away from the roadside. On the contrary, for certain elements, this logic is observed only in some stations and not in others. It is the case of As (station 4, 5, 7); Mo (station 4 and 6) and Cd (station 6). However, Cu and Mn present an anarchistic distribution of elements. A recent study (De Silva and al., 2016) stressed that spatial distribution of MTE is directly related to the type of land use, this could explain the difference in distribution of MTE in some stations.

- Cd: the isotonic map of Cd does not allow observing the evolution of the distribution while moving away from the road, except for station 6 where the distribution is normal with a reduction of the concentration while moving away from the roadside.

- Co: a normal distribution is noted in the analysis of the isotonic map for all the studied stations. This allows visualizing the reduction in the Co concentration while moving away from the road and supports that the contribution of this element in the studied soil is of road origin. Co which comes mainly from the tires wear is in small amount in the roadside soil. Nevertheless, this content can evolve with the age of the road.

- As: except for station 2, all the studied stations show that enrichment in As decreases while moving away from the road. This enrichment is limited, the contents are concentrated in the soils close to the road.

- Mo: the analysis of the isotonic maps of this element shows an enrichment in the roadside in some stations (1, 4.6) but does not allow detecting a reduction in the Mo content while moving away from the road. The other stations do not present any enrichment in Mo.

- Zn: stations 4 and 6 allow highlighting well the impact of the road traffic in the analyzed soil. Zn concentrations are very high in the roadside and decrease gradually while moving away. Although station 6 presents an enrichment in MTE coming unquestionably from the landfill of Oum Azza, enrichment in Zn in the soil presents a distribution characterized by high concentrations at the edge of the motorway and which decreases while moving away. This reinforces the idea that this enrichment is also of road origin.

- Cu: in the road field, Cu comes from the tires and brakes wears. Although this element is recognized in the pollution of the roadside soils (Omar and al. 2007), the analysis of the maps presents an anarchistic Cu distribution in all the stations.
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- Mn: this element rarely signaled in the study of impact of road traffic in the road field, was analyzed in this work because of its presence in the lead-free petrol. It is found in the soils of recent age in small amount. The isotonic map in this element shows that there is an enrichment in Mn but the distribution is anarchistic. Therefore, it is difficult to rely on this map to establish a close link between road traffic and this enrichment.

- Ni: The isotonic map clearly shows the enrichment of the soil in Ni in the roadside soils, then a normal distribution while moving away from the road. This element often quoted in works (My and Li 2008; Yu and al. 2008; Zhu and al.2008; Bai and al. 2009; Bian and Zhu 2009; Faiz and al. 2009;) on the pollution of soils in the road field is emitted by the abrasion of tires, brakes and the road, as well as by engine oil. Thus, it is obvious to establish a correlation between enrichment in Ni and the road traffic in the studied soils.

-Cr: Stations 4 and 5 present a normal distribution with a reduction in the content while moving away from the roadside, which is not the case for the other stations.

-Pb: The emission of Pb in the road field was often mentioned in the studies dealing with this topic. Although the addition of Pb is forbidden in petrol, it is emitted by the abrasion of tires.
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Figure 4 Isotoneur maps by Kriging of the MTE.

Therefore, its presence in the road emissions remains effective. The analysis of the isotonic maps of the analyzed elements has allowed highlighting the spatial distribution of some metals, but that is not the case for all the studied elements. Co, As and Cu show a normal and homogeneous spatial distribution, testifying to the impact of the road traffic in the soils. It is also important to highlight the significant role that the vegetation cover plays in the distribution of these elements because it is not always equal. We analyzed the concentrations of heavy metals of the roadside soils along the Rabat-Sale highway. The results showed that the average concentrations of metals in the soils are lower than in ordinary soils (Baize, 1997). Nevertheless, a metal enrichment (Cu, Pb, Zn, Ni, Co, Mn and Cr) coming from the traffic was highlighted in comparison with the testing soil. The distribution of metals is done horizontally for some elements and others not (figure 4). This analysis combined with that of the land use map (Figure 4) shows that the distribution of MTE in the road field is closely related to the land use and that the road traffic is not the only element to be taken into account in the metal enrichment of the soils; there are other anthropogenic sources responsible for the pollution of the analyzed soils (landfills, factories). The analysis of the Pearson correlation showed positive and significant correlations between some studied elements (Pb, Zn, Mo, and Cu); it is less for others (As, Cd). No significant relation was established between the analyzed MTE and physico-chemical parameters. The generalization of fuels without lead (since January 2000)
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has led to a significant decrease of lead pollution. But, lead is still present in the fuel, the brakes wear, engine oil, bearings, the pneumatic tires wear and the abrasion of the road (Aslam and al., 2011, Lee and Touray, 1998, Lough and al., 2005). The lead content in the soil remains up-to-date and its evolution should not be overlooked. The Cd contamination is done in very small amount within the framework of the road traffic, but will certainly continue because of the use of cadmium stearate like stabilizing rubbers and lubricant additives. Cadmium is also an impurity related to zinc and zinc coated steels release cadmium. It is important to note that the quantity of the pollutants found in the roadside soils also depends on the parameters such as speed, density and the type of car.

5. CONCLUSION
Several studies have allowed highlighting the contamination of surface soils with road traffic. This relation often was established for some elements such as Pb, Cd, Zn and Cu. However, this work shows that there are other elements in direct relationship to the road traffic which are not often studied. It is the case of the Mn and the Co which were approached in this work. We observed a peak of concentration in stations 1 and 6. This distribution was related to the presence of another older motorway (A1) in station 1 and of the landfill of “Oum Azza” in station 6. As, Co and Mo were not often highlighted in the various studies on pollution in the road field, but recent studies affirm their implication in the enrichment of roadside soils.

BIBLIOGRAPHICAL REFERENCES


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