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Accumulation of heavy metals in plants at roadside in Taymma (Saudi Arabia) and its relation to traffic intensity

Salem Mesfir Al-Qahtani

Department of Biology, University College of Taymma, University of Tabuk Tabuk 71491, Saudi Arabia
e-mail: salghtani@ut.edu.sa, salghtani008@gmail.com; phone: +96-654-545-7641

Abstract: Traffic-related pollution with heavy metals in of great importance as it is transferred through food chain and affect human health. In this study, the concentrations of seven heavy metals (As, Cd, Co, Cu, Fe, Mn, Pb and Zn) in plant materials located on the roadside of six roads in Taymma (Saudi Arabia) was investigated. The studied metals showed considerable variation among the investigated roads. Only concentrations of Co (F=5.233, P=0.009), Cu (F=5.475, P=0.007), Fe (F=3.981, P=0.023), Mn (F=45.395, P<0.01) and Pb (F=5.844, P=0.006) in the roadside plants were significantly different among the studied roads. It was assumed that due to other factors such as road age. Interestingly, there was no direct relationships between the concentrations of heavy metals and the traffic intensity (average number of vehicles/day) (R2=0.154, Adj-R2=0.597, F-value=0.205 and P=0.982). The adaptability, physiological and morphological characteristics of the plant are controlling the uptake levels of heavy metals by the plant. There were negative relationships between Cd-Cu (r=-0.522, Co-Zn (r=-0.423) and Cu-Fe (r=-0.538). Meanwhile, positive relationships were detected between Mn and Pb (r=0.434). Proper bioremediation programs should be launched to reduce the adverse effects of these pollutants.

[Al-Qahtani S.M. **Accumulation of heavy metals in plants at roadside in Taymma (Saudi Arabia) and its relation to traffic intensity.** *Life Sci J* 2020;17(8):65-70]. ISSN: 1097-8135 (Print) / ISSN: 2372-613X (Online). http://www.lifesciencesite.com. 10. doi:10.7537/marslsj170820.10.

Keywords: Roadside plants; heavy metals; traffic intensity; Saudi Arabia; Taymma

1. Introduction

There is a serious concern about increasing traffic which has been proven as a substantial source of pollution (Hosseini et al., 2020). Different pollutants are emitted from the traffic including gaseous and solid materials and compounds (Cicek et al. 2012; Ahmed et al. 2016; Jimenez et al. 2018). For instance, the amount of lead (Pb) released into the environment due to traffic and transportation can reach up to 0.12 kg/ 1000 vehicles (Naszradi et al. 2004). Lead as well as other pollutants are deposited in the soil or accumulated in organisms (e.g. plants) in the roadside. Various levels of the pollution in the roadside is an important public health problem. The emission of pollutants in the forms of organic and non-organic substances are of main concern. The emission of these pollutants occur continuously and it is related to the intensity of the traffic (Aljazzar and Kocher 2016; Adamiec 2017; Jiang et al. 2017; Jimenez et al. 2018; Sabzevari and Sobhanardakani 2018; Sobhanardakani 2019; Aricak et al. 2019). Emission of other heavy metals such as zin, nickel and copper is due to wear and tear as well as corrosion of other vehicles parts such as tyres brake pads (Liu et al. 2006; Bermejo-Orduna et al. 2014; Aricak et al. 2019).

Living organisms have proven to be good bioindicators of environmental pollution. Plants usually planted in the roadside dividers in several countries. These plants are continuously and directly exposed to emitted pollutants from the traffic. According to Johnes (1991), the concentration of the Pb in the grass samples in Denmark rural roads corresponded to almost 90% of the lead concentrations found in the atmosphere. Although the lead was removed from the fuel during the last two decades, traces of Pb still can be detected in roadside soil samples and plants parts.

The uptake of heavy metals by plants vary depending on the weather, physiological and morphological factors. However, the traffic intensity can be considered as the key factors associated with elevated concentrations of heavy metals in plant tissue. The health hazards associated with accumulation of heavy metals in plant tissues are evident. The heavy metals are transferred through the food chain and ultimately effect human health. Different heavy metals show different toxic effect on human health (Flora 2002; Yang et al. 2002; Nordberg 2003; Massadeh et al. 2006). The physiological and toxicological effects of heavy metals includes alteration of enzyme activities, anemia, neurological disorder, hepatic, renal and respiratory effects. For example, trace concentrations of cadmium and lead are considered very toxic to living organisms and human due to their intereference with genetic structure and metabolism activities (Hosseini et al., 2020). The toxic concentrations of heavy metals vary depending on the type of the element. For example, copper is an essential element to human body, the increasing concentrations can result on hormonal disruption, cancerous and non-cancerous effects. The World Health Organization (WHO) reported tolerable weekly intakes of Cd and Pb as 0.007 and 0.025 mg kg−1 body weight, respectively, for all human groups (WHO 2000).

Application of plants as bioindicators of the environmental pollution due to traffic in the roadside has been known as excellent tool for biomonitoring and environmental assessment. Furthermore, these plants can act is a bioremediation tools so they can determine and reduce the distribution of heavy metals in the surrounding environment (Malizia et al. 2012; Bonanno 2013; Yan et al. 2013; Wiseman et al. 2014; Galal and Shehata 2015; Zhang et al. 2016). Therefore, plants are important tools to study traffic-related pollution by heavy metals (Jankowski et al. 2019, Hosseini et al., 2020). There are several studies demonstrated the ability of plants to remove heavy metals from the soil and the air. Examples of these plants are; Taraxacum officinale, Plantago major and Urtica dioica (Malizia et al. 2012), Dactylis glomerata, Arrenatherum elatius, and Alopecurus pratensis (Jankowski et al. 2019).

Although accumulation of traffic-related pollution of heavy metals has been intensively studied in several countries, such studies in Saudi Arabia are either scare of totally absent. In this study, we investigated the concentrations of seven heavy metals; As, Cd, Co, Cu, Fe, Mn and Zn in plants samples collected from roadsides in Taymma roads (Tabuk, Saudi Arabia). The present study is considered as the first effort to address the traffic-related pollution with heavy metals in Taymma and its relation to the traffic intensity.

2. Material and Methods

Study Site

Tyamma is located in Tabuk region towards the northwestern direction and is located in the northern part of Arabian Peninsula (Figure 1). Taymma has a vital connection road that lead to Al Madinah Almonwarah which is the destination for pilgrims (Hajis) during the Haj session especially those travelers coming from Jordan, Syria and Iraq. Taymma is characterized with arid climate with annual rainfall less than 100 mm. On the other hand, there is a huge project of NEOM which was announced in the last two years and this associated with increasing transportation of large and medium vehicles.

Plant Sampling

The plant samples were collected from the roadside and were transferred into labelled plastic bags. The samples were transferred to the laboratory. In laboratory, the aerial parts of the plants were separated and washed tap water then distilled water. Thereafter, the plant samples were dried using oven at temperature 70 C for 48 hours. After the samples were completely dry, they were grounded into fine powder. The samples were kept at 4 C for further analysis (Wang et al. 2018, Hosseini et al., 2020).

Heavy metal analysis

The dried plant samples were digested following the method of the direct aqua-regia (ratio 4:1) of concentrated HNO_3 (AnalaR grade, BDH 69%) and $HClO_4$ (AnalaR grade, BDH 60%). A 200 mg of each dried plant sample was transferred into 50ml flask. The initial digestion was carried out at lower temperature (40±2 C) for 1 hour and the temperature was slowly elevated to 140 C for 3 hours to ensure complete digestion of the samples. Thereafter, the solution was diluted by 40 ml of distilled water and filtered through filter papers (Whatman No.1). The analysis of heavy metals was performed using Flame-Atomic Absorption Spectroscopy (FAAS; Perkin Elmer Model AAnalyst 800) and the concentrations of the metals were expressed as mg/kg dry weight. Seven metals were analyzed; As, Cd, Co, Cu, Fe, Mn and Zn.

During taking the readings of the heavy metals concentrations, the quality control sample was periodically analyzed. All glassware and tools used in samples processing and analysis are washed in 10% HNO3 and double distilled water. The Certified Reference Materials (CRM) for Soil (International Atomic Energy Agency, Soil-5, Vienna, Austria) was utilized to ensure acceptable quality of direct aqua-regia method. The CRM was processed similarly to the samples. The heavy metals concentrations results were compared to the CRM value.

Traffic intensity

The traffic intensity was expressed as the average number of passing-by vehicles per day. The counting was conducted for 6 hours during daytime and 6 hours during the nighttime. The 6-hours period was rotated to ensure randomization. The total number of vehicles were counted each day (number of vehicles during daytime+number of vehicles during nighttime) x 2. This procedures were repeated in randomly three days a week for a period of four weeks. At the end, the average number of vehicles per day was calculated.

Statistical analysis

Data were analyzed for the mean and standard deviation (SD). The procedure of one-way ANOVA was conducted to compare the means of heavy metals concentrations among the studied sites (i.e. roads). This was conducted using IBM SPSS software package (version 22.0, IBM Corp., Armonk, New York, USA). The linear model was used to investigate the relationship between traffic intensity (average number of vehicles per day) against the concentrations of the studied metals. This was performed using the function lm in vegan package (Oksanen et al., 2017) of R program 3.5.3 (R Core Team, 2013).

3. Results and Discussion

As presented in Table 1, concentrations of heavy metals in plant tissues collected from the roadside of Taymma (Saudi Arabia) showed considerable variation. For arsenic (AS), the highest concentrations was reported in Site 2 followed by Site 6 with concentrations of 1.417 and 1.390 mg/kg, respectively. However, the lowest concentration of As was reported in Site 5. At Site 3, the plant accumulated the highest levels of Cd (13.393 mg/kg), meanwhile the lowest concentration of Cd was recorded in Site 4 (3.473). The highest concentrations of Co (22.630 mg/kg) and Cu (428.847 mg/kg) were reported in Site 4 and Site 5, respectively. The iron (Fe) fluctuated among the sites and peaked the highest concentrations in the samples collected from Site 2 (27.830 mg/kg). Interestingly, the concentrations of Pb showed to be high in Site 6 with value of 44.150 mg/kg, meanwhile the highest concentration of Mn was reported in Site 6 with level of 9.317 mg/kg. For zinc (Zn), the highest concentration of 28.623 mg/kg was recorded in Site 2 and the lowest concentration of 15.963 mg/kg was reported in Site 6.

The traffic is evidently the main source of environmental pollution in the roadsides. This was widely reported in several studies from different countries such as Brazil (Bernardino et al., 2019) Jeddah in Saudi Arabia (Kadi, 2009), Fiji (Maeaba et al., 2019), Canada (Nazzal et al. 2013), UAE (Aslam et al. 2013), Jordan (Al-Khashman, 2004), China (Wei and Yang, 2010; Yan et al. 2018) and Iran (Hosseini et al., 2020). It is reported that emitted heavy metals due to traffic have the ability to be accumulated in the plants in the roadside or in the vicinity of roads (Hosseini et al, 2020). The plants uptake the heavy metals through either stomata or through the rooting system (Nabulo et al. 2006; Feng et al. 2011; Jankowski et al. 2015). For instance, the Pb in the roadside plants was reported to be accumulated through dispositioning in the stomata (Nabulo et al. 2006; Sawidis et al. 2011). However, other researchers argued that the accumulation of heavy metals in the roadside plants occur mainly through the rooting system pathway (Wang et al., 2018).

Table 1: Mean±SD of the heavy metals concentrations (mg/kg) from the plant samples collected from roadsides in Taymma, Saudi Arabia.

	As	Cd	Co	Cu	Fe	Mn	Pb	Zn
Site 1	0.373±0.647	5.993±6.611	10.440±4.197	281.063±365.503	9.955±3.243	0.193±0181	36.870±30.273	16.167±6.311
Site 2	1.417±0.787	10.837±9.300	2.433±2.497	137.815±83.957	27.830±17.860	0.247±0.219	2.703±4.682	28.623±4.764
Site 3	1.073±0.911	13.393±3.736	18.973±11.808	194.873±141.228	11.633±6.508	2.423±0.841	7.795±1.393	16.820±11.001
Site 4	0.343±0.595	3.473±4.356	22.630±8.422	903.21±101.523	0.120±0.208	2.277±0.952	0.300±0.519	19.660±7.800
Site 5	0.197±0.341	3.837±5.383	1.880±0.381	428.847±322.277	4.425±3.816	7.647±1.446	20.033±2.631	19.117±8.005
Site 6	1.390±1.210	7.180±6.089	9.610±3.420	155.263±63.810	9.817±4.209	9.317±1.471	44.150±9.768	15.963±7.744

Table 2: One-way ANOVA results showing the comparison of the heavy metals concentrations in plant samples among the studied roads in Taymma, Saudi Arabia.

	Mean Square	F-value	P-value
As	0.935	1.475	0.269
Cd	46.715	1.223	0.357
Co	214.588	5.233	0.009
Cu	254411.658	5.475	0.007
Fe	268.156	3.981	0.023
Mn	45.000	45.395	<0.001
Pb	1015.793	5.844	0.006
Zn	65928.200	2.777	0.068

The concentrations of Co, Cu, Fe, Mn and Pb in the plant materials were significantly different among the studied sites (Table 2). There are several factors that result in variation in the heavy metals concentrations in the plant tissues besides plant physiology and adaptation. The road age and intensity of the traffic can be considered as important factors controlling the deposition of the heavy metals in the roadside soil and plants. For instance, Silva et al. (2016), Galal and Shehata (2015), and Khalid et al. (2018) stated that traffic intensity corresponded to elevated concentrations of Cd, Cu, Pb, Ni and Zn in the soil and ultimately plants. In addition to that, the wear and tear of vehicles' parts was found to be associated with high concentrations of several heavy metals such as Cd, CU, Fe and Zn in the surrounding environment (Jiang et al., 2017).

There was no relationship between the traffic intensity (expressed as average number of vehicles/ day) and the concentrations of heavy metals in the plant tissues collected from roadside (Table 3). Although it was widely reported that concentrations of heavy metals in roadside soils are correlated with traffic intensity. In this study, we did not detect a significant relationship between the studied metals and the traffic intensity (average number of vehicles/day). This was not in agreement with several reports which concluded that soils' content of heavy metals is positively correlated with traffic intensity (e.g. Khalid et al., 2018). There are several reasons which may result in such discrepancy. As stated earlier, the morphology and physiology of the plants contribute in their ability to uptake the heavy metals either from air or from soil.

Table 4 presents the correlation results (Pearson correlation test) among the studied heavy metals. There was a significant negative relationship (r=-0.522) between Cd and Cu, between Co and Zn (r=-0.423) and between Cu and Fe (r=-0.538). However, there was a significant positive relationship between the concentrations of Mn and Pb (r=0.434).

Table 3: Summary of the linear model between average number of vehicles and the concentrations of heavy metals in the plant materials on the roadside of Taymma, Saudi Arabia. Residual standard error=2403, multiple R^2=0.154, Adj-R^2=0.597, F-value=0.205 and P-value=0.982.

	Estimate	**Standard error**	**t value**	**P-value**
Intercept	2952.889	3151.444	0.937	0.373
As	26.926	81.776	0.329	0.749
Cd	-192.110	895.138	-0.215	0.835
Co	-11.005	126.780	-0.087	0.933
Cu	19.950	80.809	0.247	0.811
Fe	2.096	3.246	0.646	0.535
Mn	41.062	76.017	0.540	0.602
Pb	43.921	188.193	0.233	0.821
Zn	6.723	38.955	0.173	0.867

Table 4: Pearson correlation coefficient (r) between the heavy metals concentrations in plant tissues collected from roadsides of Taymma, Saudi Arabia.

	As	**Cd**	**Co**	**Cu**	**Fe**	**Mn**	**Pb**	**Zn**
As	-	0.035	0.190	-0.353	0.259	-0.024	0.040	0.007
Cd		-	0.087	-0.522*	0.339	-0.196	-0.042	0.020
Co			-	0.288	-0.334	-0.212	-0.210	-0.423*
Cu				-	-0.538*	-0.020	-0.380	-0.148
Fe					-	-0.283	-0.137	0.366
Mn						-	0.434*	-0.134
Pb							-	-0.182
Zn								-

*Significant at P<0.05.

Conclusion

The levels of heavy metals in roadside plants were investigated in six roads of Taymma, Saudi Arabia. The concentrations of heavy metals showed notable variation among the studied sites especially Co, CU, Fe, Mn and Pb. No relationship was detected between the heavy metals concentrations and the traffic intensity. This variation is not merely related to the traffic intensity but it might be related to other factors such as plant physiology, morphology and adaptability. Further studies concerning investigating the physiological adaptability in the roadside plants will be interesting.

Acknowledgment

This study was supported by the Research Grant (S-1440-0076) provided by The Deanship of Scientific Research, University of Tabuk.

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8/17/2020