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# Determination of Selected Heavy Metals Concentration in Soil along the East-West Highway Road Shoulder in front of UMK Jeli Campus, Jeli, Kelantan, Malaysia

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***Abstract***

*Road shoulder receives all pollutants associated with runoff including heavy metals from the moving vehicles on the road. The pollutant will eventually end up in the river nearby or shallow groundwater. Thus, the concentration of heavy metals in the road shoulder soils along the East-West highway in front of UMK Jeli Campus, Kelantan, Malaysia was studied. The main objective of the study was to determine the concentration of selected heavy metals, namely Zn, Pb, Mn, Cd and Cu in the soil at the road shoulder. The soil samples were collected from ten stations along the East-West Highway and analyzed for the concentration of selected heavy metals using Atomic Absorption Spectrophotometer (AAS). To support the findings, a traffic count was conducted. It was found that the average number of vehicles using this road ranged between 1,563 vehicles per day in the morning and 1,819 vehicles per day in theevening.90% of the vehicles were powered by petrol engines. The results show that the mean concentration of Mn was the highest (10.3011 mg/L) and Cd concentration was the lowest (0.0116 mg/L). On the other hand, the mean concentration of Zn was 4.4824 mg/L, Pb was 2.1378 mg/L, and Cu was 0.5608 mg/L. All the mean concentration of heavy metals was higher as compared to the Natural Range of Heavy Metals (NRHM) and Critical Limits for Heavy Metals Concentration (CLHMC) in soil except for Mn. However, there were no significant different (P>0.05) of heavy metals concentration between sampling stations. The values of the heavy metal suggest that vehicle is the main source of heavy metals contamination in the road shoulder soils since there are no other activities in the vicinity. The results of the study provide information on the concentration of heavy metals in the road shoulder that can be used as a basis to develop the Heavy Metal Allowable Limits (MSHMAL) in soil for Malaysia.*

***Keywords:*** *AAS, road shoulder, Jeli, East-West Highway, heavy metals, soil, shallow groundwater*

## 1. Introduction

Heavy metals are naturally present in the environment, but the concentration levels are usually low and unharmful to human, animal, and plant. The density of heavy metals is of 6.0 g/cm$^3$ or more which is higher than average particle density of soils. The most common heavy metals related to the potential hazard in polluted soils are cadmium (Cd), lead (Pb), copper (Cu), and zinc (Zn). Generally, the sources of manmade heavy metal pollutions come from metal smelting, waste disposal and fossil fuel combustion

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(Koldabadi et al., 2012) but nowadays, road and vehicle are regarded as the largest contributors of heavy metals. Tyre wear and tear emit zinc while brake pads and lining emit copper. When motor oil builds up metals as it comes into contact with the surrounding components during the running engines, oil leaks will become another route to release heavy metals into the environment (Chinwe et al., 2010). Fossil fuel combustion releases heavy metals into the environment through exhaust emission. The emissions which consist of heavy metals will seep into the soil through road shoulder (Amusan et al., 2003). Apart from that, the heavy metals are able to enter the groundwater by leaching.

Road is the most important infrastructure that vitalizes the economic and social activities. Improved road accessibility will bring many job opportunities, such as auto-electrician, welders, and auto-mechanic (Abechi et al., 2010). Yet, the road construction has led to environmental pollution (Bai et al., 2008). Construction of road also causes loss of productive agriculture lands, change of demographic and disruption of economic activities. The bitumen and mineral filler material used in the construction of highway road contain different heavy metal species such as Cu, Zn, Cd and Pb (Zhang et al., 2012). The properties of the road will affect the vehicle performance and characteristic including ride comfort, handling, fuel consumption, and tyre wear (Johnson & Odelius, 2012). The matter that accumulates on the road surfaces is usually a heterogeneous mixture of organic and inorganic substances. Large organic matter can be originated from the decaying leaves and animal body. Meanwhile, the deposition of contaminants can be originated from atmospheric fallout, vehicle exhaust emissions, wear and tear, degradation of pavement, maintenance of the road, various processes of industrial, dust and mud falling from the underside of vehicles (Kumar et al., 2002). Road surfaces are impenetrable and act as temporary sinks for a variety type of contaminants that washed off during rainfall to the surrounding, especially the road shoulder soil (Charlesworth et al., 2003). The road can influence the frequency, intensity and spread of disturbances on the surrounding environment. If the road surfaces, drainage patterns and slope stability are altered, the soil erosion, sedimentation and landslides will increase (Eker & Coban, 2010). Furthermore, road shoulder soils with tree planted show significantly lower concentration of Cu and Pb compared to those without tree planted on it (Zhang et al., 2012). Generally, the longer the usage history of the highway road, the higher the concentration of heavy metals in the road shoulder soils because it is proportionally related to traffic volume (Chen et al., 2010). Road with a higher average traffic flow produces more pollutant associated with runoff compared to the normal traffic flow (Chinwe et al., 2010). The wear during the sunny weather is almost insignificant compared to the rainy weather. The wear of a wet surface road is proven to be two to six times more than the dry condition (Backstrom et al., 2003). The heavy metal concentration is higher in the road shoulder soils along the uphill of the road due to the increasing rate of vehicle emission. When going downhill, less emission is emitted due to less power is required to move the vehicle. In addition, the concentrations of heavy metals in road shoulder soils decline with the increase of distance from the road. The heavy metal concentration declines due to the emission of heavy metals from the vehicle exhaust are forced to settle by gravity nearer to the road shoulder (Amusan et al., 2003). Heavy metal concentrations are higher in the centre of the road and decreased towards the road shoulder (Deletic & Orr, 2005).

It is undeniable that the emissions and combustion of fossil fuel from the vehicle has polluted the environment and must be controlled (Karlsson, 2004). The traffic vehicles introduced a number of heavy metals into the environment and were released to the nearby road shoulder soils. An additive to petrol such as tetraethyl lead [$(C_2H_5)_4Pb$] was the main source of lead in vehicle exhaust emission (Amusan et al., 2003). The vehicle's emission relies on the vehicle speed, vehicle mileage, age of the vehicle and the rate of emission of different vehicle categories (Padam & Singh, 2001). The more energy needed to move the vehicle, the higher the level of emission from the vehicle exhaust and most of the emissions were deposited to the nearest road shoulder soils (Amusan et al., 2003). Apart from that, a different type of vehicle in traffic would emit different quantity and type of heavy metals (Seqzin et al., 2004). The heavy metal released from the vehicle such as Cu, Zn, Pb and Cd generally released from wear of tyre rather than engine combustion. It was also found that heavy-duty vehicle emits more Cu than light-duty vehicles (Sternbeck et al., 2002).

In Malaysia, there was limited information on heavy metals contamination in soils and it was not possible to make an accurate assessment on heavy metal contamination in soil (Rahman et al., 2000). In addition, Malaysia does not have any standard guidelines for heavy metal content in the soil. Thus, the results of the study were compared with the Natural Range of Heavy Metals (NRHM) (Okeyode & Rufai, 2011) and Critical Limits for the Heavy Metals Concentration (CLHMC) (Wim de Vries et al., 2002) in soil.

Generally, heavy metal on the road shoulder soils was caused by runoff. When the rain falls onto the earth surface, it would flow downhill according to the gravity, and some of the precipitation would seep into the groundwater. Runoff happens only if the precipitation rate surpasses the infiltration rate of water into the soils. Runoff that happens on the surfaces before flowing into a channel was also known as the non-point source. When a non-point source consists of contaminants produce by a human, it was known as non-point source pollution (Musa et al., 2010). Road runoffs are a mixture of contaminants released into the surrounding environment without prior treatment (Chinwe et al., 2010). As the runoff flows along the road, some of the contaminants such as heavy metals were accumulated. The heavy metals would seep into the road shoulder soil, and some will be discharged into the streams and groundwater. Vegetation nearby the road shoulder would uptake the heavy metal and eventually it was transferred into the human diet. The consumption of groundwater by humans would also be affected by heavy metal poisoning (Musa et al., 2010). The magnitude of the heavy metals found in the runoff are site-specific and are influenced by a few factors such as the traffic volume, the road design, climate and nearby land use. Road with higher average daily traffic is proven to produce more pollutant than a rural highway (Chinwe et al., 2010).

Thus, this study was taken to determine the concentration of selected heavy metals namely Zn, Pb, Mn, Cd and Cu in the soil at the road shoulder along the East-West Highway in front of UMK Jeli Campus, Kelantan, Malaysia in order to get baseline data for the development of Malaysia Standard as well as crafting mitigation measures to minimize the impact.

## 2. Materials and Methods

The district of Jeli is the gateway of Kelantan for the West Coast of Peninsular Malaysia. It is an ideal stopover point for those who are travelling from the East Coast to the West Coast and vice versa, through the East-West Highway. In addition, the district of Jeli also links to the South of Kelantan by Jeli-Dabong highway. In terms of location, Jeli district is bordered by Thailand in the north, the Tanah Merah District in the east, Kuala Krai District and Gua Musang District in the south and Perak in the west. Jeli town is the main town in this district. It is located about 98 kilometres from Kota Bharu through the East-West highway.

The sampling area is 500 metres long road shoulder along the East-West highway in front of UMK Jeli Campus, Kelantan, Malaysia (Figure 1). Sampling stations were identified at every 50 metres interval with a total of 10 sampling stations.

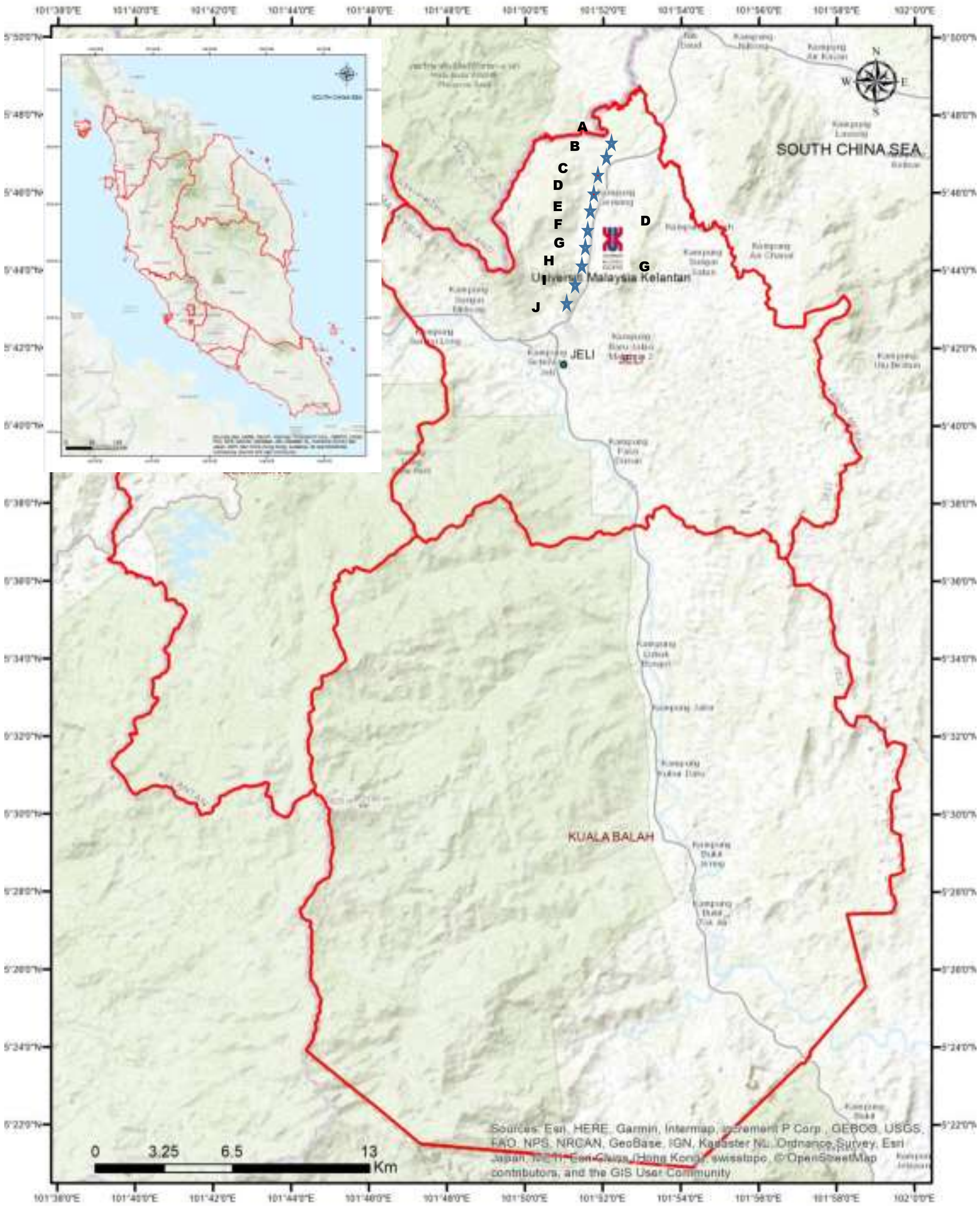


**Figure 1: Study Site**

Pollutant concentrations in soil at the road shoulder usually related to the number of vehicles. Therefore, a traffic survey was conducted. The vehicles were counted from both directions. The survey was conducted during the peak hours from 8.00 am to 10.00 am and from 5.00 pm to 7.00 pm in weekdays (Sunday, Tuesday, and Thursday) and in weekends (Friday and Saturday) from 10.00 am to 12.00 pm and 5.00 pm to 7.00 pm. The counted vehicles were classified into two categories which are petrol vehicle and diesel vehicle. The soil sample was collected at the depth of10-15 cm from the surface and stored in clean polythene bags. Two soil samples were collected from each station, at the above-mentioned distances from each station, with a stainless-steel trowel. Samples were sealed in polythene bags and subsequently treated and analyzed separately.

Before soil sample can be analyzed using Atomic Absorption Spectrophotometer (AAS), it has to be prepared to suit the machine where samples were ground using an acid pre-washed mortar and pestle sieved by passing them through a 600$\mu$m mesh. 10g of soil from each sample was accurately weighed and treated with 50 ml of concentrated $HNO_3$ (Perkin-Elmer, 1996). The digested soil sample was then warmed on the hot plate until the sample is reduced to half. 50 ml of concentrated $HNO_3$ was added to the digested soil sample again and was warmed on a hot plate until the sample is reduced to half. The digested soil sample was left to cool down and shaken before filtered. The digested soil sample was filtered by using 0.45$\mu$m filter papers, and the volume of filtered soils was adjusted to 100 ml with distilled water. In this case, metal contamination is expressed in mg/L of the leachable metal (Raymon & Felix, 2011) and compared with the Natural Range of Heavy Metals (NRHM) and Critical Limits for the Heavy Metals Concentration (CLHMC) in soil.

## 3. Results and Discussion

The type of vehicle is divided into two categories which are diesel and petrol based on findings made by Sternbeck et al. (2002), a heavy-duty vehicle will emit more Cu than light-duty vehicles. From the data obtained, it was observed that the amount of petrol vehicle on the road (1,226) was higher than the diesel vehicle (142). This is because there was no major industrial area around the sampling area. There were a lot of residences and other facilities such as hospital, post office, market, and shop lots. The diesel vehicles were mostly the bus, four-wheel drive (4WD) and the lorry. Meanwhile, petrol vehicles consist of car and motorcycles. Although the sampling station was located in a rural area, the volume of vehicle traffic was higher than any rural road. The reason is, this was the only road available for the vehicles to travel from east to west or vice versa as there was no other alternative road. The average vehicle using this road in the morning is about 1,563 vehicles per day, meanwhile in the evening around 1,819 vehicles per day. So, this road is considered as high-volume rural roads because country and township roads that had fewer than 400 vehicles per day are classified as low – volume rural roads (Eugene, 2003). According to Hall et al. (2003), low-volume roads have varied categorization based on average daily volumes less than 200 to 1000 vehicles per day.

The road shoulder soil zinc concentration ranged from a low concentration of 3.381 mg/L at Station A to a high concentration of 5.678 mg/L at Station F with the mean concentration of 4.4824 mg/L. Analysis of variation of Zn among the station indicated that there was no significant variation ($p>0.05$) between stations. The high concentration in Station F was believed to be due to the heavy traffic at the road junction. According to Abechi et al. (2010), the traffic junction and crossroads record a higher concentration of heavy metals. Therefore, it was not surprising that a high concentration of Zn was found at Station F's junction, where it is the main entrance to UMK Jeli Campus. The mean concentration of Zn was far higher than the Natural Range of Heavy Metals (NRHM) for the concentration of zinc in the soil which is between 0.05 mg/L to 1.5 mg/L (Okeyode & Rufai, 2011). But it was within the range for the soils of England and Wales, where it was ranged from 0.05 mg/L to 36.48 mg/L (Akbar et al., 2006). It is observed that there were no other major industry activities exist in the study areas such as smelting industry, so it is believed that the main source of Zn was probably from the wear and tear of vehicle rubber tires due to poor or rough road surfaces. Zinc can also be derived from the lubricating oils in which Zn was found as part of many additives, including zinc dithiophosphates (Abechi et al., 2010). Zinc could be toxic to plants if present, even in a small amount (Okeyode & Rufai, 2011). Although zinc was not a carcinogen to human but excessive intake through food chain that was contaminated with heavy metal zinc could lead to dehydration, abdominal pain, lethargy, vomiting and dizziness (Chinwe et al., 2010). Therefore, it could be concluded that zinc concentration in the soil along the highway in front of UMK Jeli Campus was high, and it exceeded the NRHM (Table 1 and Figure 2).

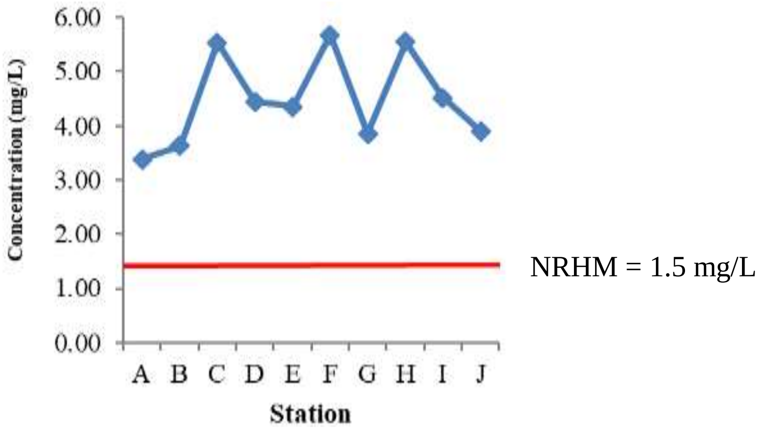


**Figure 2. Concentration of Zn across the Sampling Station**

In the present study, the lead concentration of the road shoulder soils ranged from 2.009 (Station A) to 2.987 mg/L (Station F) with an average of 2.1378 mg/L. However, statistical analysis showed that there was no significant in lead concentration between the station ($p>0.05$). The low concentration at Station A might be due to more plant surrounding the road shoulder soil. On the other hand, the high level of lead concentration at Station F was believed to be due to the construction site was closer, where diesel engine construction vehicles such as lorry and four-wheel drive (4WD) often passed by Station F compared to other stations. Mean concentration of Pb in the study area was far higher than NRHM and CLHMC, where the range of NRHM and CLHMC were between 0.075mg/L and 0.125 mg/L and 0.002 – 0.015 mg/L respectively but it was within the range of normal British soils which is ranged from 0.02 to 3 mg/L (Okeyode & Rufai, 2011; Akbar et al., 2006; Wim de Vries, 2002). The high concentration of lead from the data was believed to be caused by lead particle from gasoline combustion that eventually settled on the road shoulder soils (Abechi et al. 2010). Some researchers found that lead particle could spread for about 100m away from the main road (Qasem & Kamal, 1999). It was capable of seeping into the soil or flowing into the Sg. Buluh which was located close to the sampling station. Although the lead concentration on gasoline was reduced, the increased traffic had caused an increase of the lead emission to the road shoulder soils. Much attention had been given due to its broad usage as an anti-knocking agent in gasoline (Akbar et al., 2006). The contamination of lead in the soil brings a major problem because lead is carcinogenic to human. It could be concluded that the concentration of Pb in the soil at road shoulder along the highway in front of UMK Jeli Campus was high and exceeded the NRHM and CLHMC (Table 1, Table 2 and Figure 3).

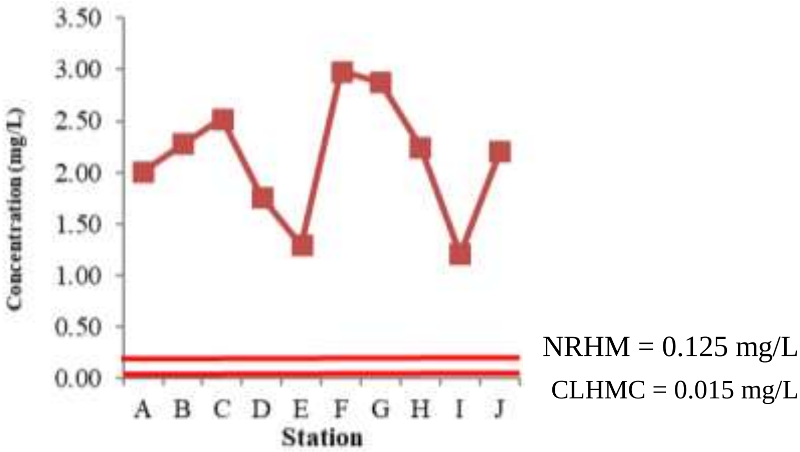


**Figure 3. Concentration of Pb across the Sampling Station**

On the other hand, the concentration of copper was ranged between 0.403 mg/L (Station A) and 0.860 mg/L (Station E) with a mean concentration of 0.5608 mg/L. However, based on statistical analysis, there were no significant different (P>0.05) in terms of concentrations between the sampling stations. The high concentration in Station E was probably caused by the heavy traffic at the road junction. The traffic junction and crossroads indicated a higher concentration of heavy metals (Abechi et al., 2010). Apart from that, Cu usually unable to travel far because it is strongly attached to the organic matter and minerals in the soil (Najib et al., 2012). Perhaps this explains a high Cu concentration in soils at Station E. Cu was usually released from thrust bearings, bearing metals and engine wear. Other vehicle wastes, including copper wire, electrodes electrical and electronic part also generated by a high amount of copper particles to the environment. If the vehicle's waste was released to the surrounding for a long time, it would gradually rust and leach into the soil through runoff. Eventually, this will cause phytotoxicity. It is shown that if Cu ends up in the soils, it will strongly attach to organic matter and mineral. Therefore, Cu does not travel very far after it been released to the surrounding (Najib et al., 2012). Generally, the mean concentration of Cu along the road shoulder in front of UMK was higher as compared to NRHM, where NRHM ranged from 0.035 to 0.400 mg/L (Okeyode & Rufai, 2011) but it was within the concentrations of soil in England and Wales, which was ranged from 0.012 to 1.508 mg/L. The finding was in-line with Akhbar et al. (2006), where they reported that the concentration in urban road shoulder soils was 5 - 10 times higher than the normal concentration (Akbar et al., 2006). The mean concentration of Cu found in the study area was higher than the NRHM (Table 1 and Figure 4).

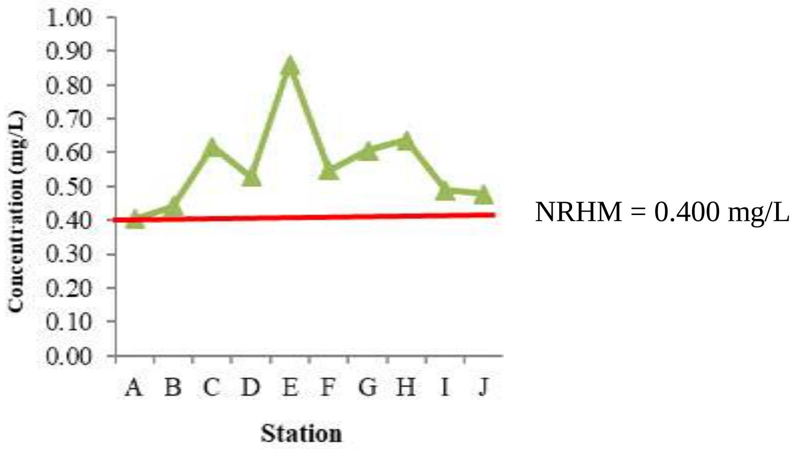


**Figure 4. Concentration of Cu across the Sampling Station**

The manganese concentration in the road shoulder soil along UMK Jeli Campus ranged from 6.661 (Station A) to 16.600 mg/L (Station G) with the mean concentrations of 10.3011 mg/L. However, Mn concentration were not different ($p>0.05$) between sampling stations. The mean concentrations of Mn fall within NRHM, which is ranged from 1.00 – 45.00 mg/L (Okeyode & Rufai, 2011). These indicated that Mn in the studied area was within the safe level and less influenced by human activities. Mostly, the presence of Mn particles in the soil of all stations might be from parent material in the soil but some sources perhaps emitted from motor vehicle exhaust. It is known to be carcinogenic, physiological, neurological damage to human and animal. There were two mechanisms compromised in defining the retention of manganese in the environment by soil. Firstly, manganese was capable of adsorbing other oxides, hydroxides and oxyhydroxides by ligand exchange reactions. Another mechanism was through cation exchange reactions. Manganese oxides, hydroxides and oxyhydroxides could be formed from manganese ions and the charged surface of soil particles. Eventually, it would form absorption sites for other heavy metals (Dube et al., 2001). The mean concentrations of Mn found in the study area was within the NRHM (Table 1 and Figure 5).

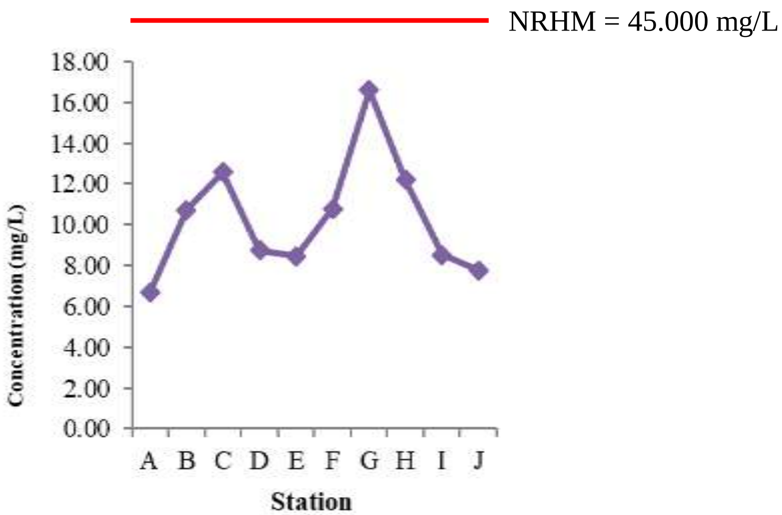


**Figure 5. Concentration of Mn across the Sampling Station**

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The concentration of cadmium in the soil of the road shoulder along UMK Campus Jeli which, was obtained ranged from 0.001 (Station A) to 0.034 mg/L (Station H) with the mean concentrations of 0.0116 mg/L. However, based on statistical analysis, the concentrations of Cd were not different between stations ($p>0.05$). The possible reasons for the high concentration at Station H might be the same as Pb. During soil sampling, there was an ongoing construction work held near to the station. Lorry and four-wheels drive vehicle passed through the station. Concentrations of Cd was found to be far higher as compared to CLHMC, where it ranged from 0.0003 mg/L to 0.0008 mg/L. The concentration of Cd was also higher as compared to the background concentration of Cd in soils of Britain, which is 0.01 mg/L. It was also mentioned that the concentrations of Cd below 0.01 mg/L indicated the soil was not contaminated. Cd concentration from 0.01 to 0.03 mg/L indicated slight contamination whereas 0.03 to 0.1 mg/L indicated contaminated soil (Akbar et al., 2006). So, the mean concentrations of Cd at the road shoulder in front of UMK Jeli Campus was within the slight contamination categories. The existent of Cd particles in the road shoulder soil along UMK Jeli Campus was believed to be due to lubricating oils, and old tires that were regularly used on the rough surfaces of the roads which intensified the wearing of the tires (Dehghani et al., 2017). Cd may also come from PVC product, alloy, and a car battery. There was a potential for the Cd compound at the road shoulder soil along UMK Jeli Campus to seep into the groundwater and river. Sg. Buluh is the river located close to the sampling area could be contaminated with Cd. A long-term high Cd exposure may cause damage in human skeletal system (Jarup, 2003). It could be concluded that the concentration of Cd in road shoulder soil in front of UMK Jeli Campus was far higher as compared to CLHMC (Table 2 and Figure 6).

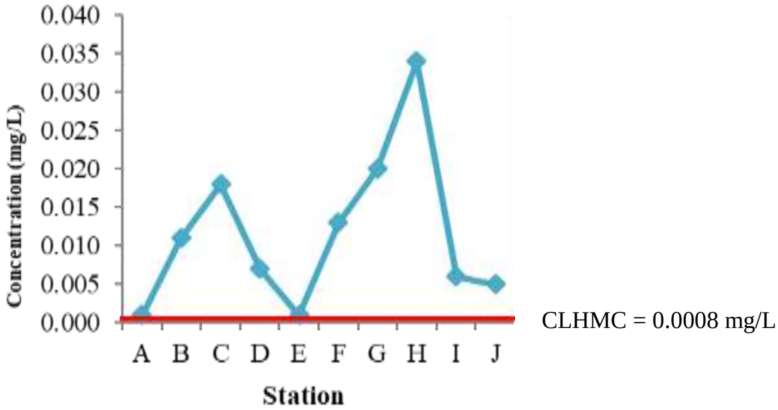


**Figure 6. Concentration of Cd across the Sampling Station**

**Table 1: The Natural Range of Heavy Metals (NRHM) in Soil**

| Parameters | Standard (mg/L) | Mean Concentrations Obtained (mg/L) |
|---|---|---|
| Manganese (Mn) | 1.000 – 45.000 | 10.3011 |
| Copper (Cu) | 0.035 – 0.400 | 0.5608 |
| Zinc (Zn) | 0.050 – 1.500 | 4.4824 |
| Lead (Pb) | 0.075 – 0.125 | 2.1378 |

**Table 2: The Critical Limits for Heavy Metals Concentrations (CLHMC) in Soil**

| Parameters | Standard (mg/L) | Mean Concentrations Obtained |
|---|---|---|

| | | (mg/L) |
|---|---|---|
| Cadmium (Cd) | 0.0003 – 0.0008 | 0.0116 |
| Lead (Pb) | 0.0020 – 0.0150 | 2.1378 |

## 4. Conclusion

The result of this study revealed that road shoulder soils along UMK Jeli campus were relatively contaminated with heavy metals, namely Pb, Zn, Cu and Cd. Although Mn concentration was the highest among the heavy metals studied, the Mn falls within the natural range. Since there was no major industry, the sources of the heavy metals were mainly from the emission of the vehicle such as fossil fuel combustion, tyre wear and brake pads tear. The emissions of heavy metal by the vehicle would seep into the soil through road shoulder. A high concentration of heavy metals was found at Station E, and Station F because both stations were located at the junction. The vehicle tends to slow down at the junction and thus more emission of heavy metals to the surrounding. The concentrations of heavy metals in the road shoulder soils along East-West highway in front of UMK Jeli campus were in the order of Mn>Pb>Zn>Cu> Cd but it shows insignificant ($p>0.05$) between station. Hopefully, the findings of this study can be a basis for the development of Malaysia Standard for Heavy Metal Allowable Limits (MSHMAL) in soil.

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