COMPARISON OF Pt, Rh, Cu, Zn, Pb AND Ni CONCENTRATION IN ROAD DUST SAMPLES OF GENTING SEMPAH TUNNEL, PAHANG

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Abstract

An increasing usage of motored vehicles in modern mode of land transportation has an impact to the distribution of certain heavy metals in the environment. Zn, Cu, Pb, Ni, Pt and Rh are elements known to be associated with motored vehicles activities. The study was carried out to determine the concentration of these elements in road dusts samples from closed sampling area i.e. Genting Sempah Tunnel from January to December 2006. The tunnel was selected because an average of 836092.5 unit vehicles passed through the tunnel monthly. The elemental contents of Zn, Cu, Pb, Ni, Pt and Rh in the road dusts samples were determined using Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES). The results shows that the monthly average concentration of the elements in road dusts samples are 1886.7 ± 868.3 µg/g, 213.2 ± 18.2 µg/g, 155.6 ± 29.0 µg/g, 23.5 ± 0.3 µg/g, 5.8 ± 0.6 µg/g and 2.6 ± 0.5 µg/g Zn, Cu, Pb, Ni, Pt and Rh, respectively. However, there are no clear relation could be seen between the elemental monthly average concentrations to the monthly traffic density.

Abstrak

Peningkatan penggunaan kenderaan bermotor dalam pengangkutan darat moden mampu memberikan kesan terhadap kepekatan sesetengah unsur logam berat di dalam persekitaran. Zn, Cu, Pb, Ni, Pt dan Rh merupakan unsur yang diketahui mempunyai kaitan dengan kenderaan bermotor. Kajian untuk mengkaji kandungan unsur ini di dalam sampel debu jalan telah dilakukan di kawasan persampelan tertutup Terowong Genting Sempah bermula pada bulan Januari hingga Disember 2006. Terowong dipilih sebagai lokasi persampelan disebabkan purata bulanan kenderaan bermotor melaluinya sebanyak 836092.5 unit sebulan. Penentuan kandungan unsur Zn, Cu, Pb, Ni, Pt dan Rh telah dilakukan menggunakan analisis Spektrometri Pancaran Optik – Plasma Gandingan Teraruh (ICP-OES). Hasil kajian menunjukkan purata bulanan kepekatan unsur yang dikaji adalah 1886.7 ± 868.3 µg/g, 213.2 ± 18.2 µg/g, 155.6 ± 29.0 µg/g, 23.5 ± 0.3 µg/g, 5.8 ± 0.6 µg/g and 2.6 ± 0.5 µg/g Zn, Cu, Pb, Ni, Pt dan Rh, masing-masing. Walau bagaimanapun, tiada perhubungan jelas dapat dilihat antara ketumpatan trafik di lokasi kajian dengan kepekatan unsur.

Keywords: Heavy metals, PGE, road dust, ICP-OES

Introduction

Motored vehicles for land transportation are the foremost transportation method nowadays. Each year, consistently rising number of motored vehicles leads to the increase of traffic-related elements in the environment, especially in urban areas adjacent to traffic activities. Elements such as platinum (Pt), rhodium (Rh), copper (Cu), zinc (Zn), lead (Pb) and nickel (Ni), which were found to be in increasing concentration around these areas are believed to be originated from traffic activities.

Application of catalytic converters in cars exhaust system, as an attempt to reduce air pollution, has lead to the existence of Pt and Rh in the environment [1-5]. Catalytic converters are used to change harmful pollutants such as soot, CO and NO_x from a burning fuel in an engine into environmental-friendly compound such as CO_2, H_2 and H_2O,. The converter is located at a suitable point in the exhaust pipe line, so as that emission from the burning fuel, heat and air are in appropriate ratio for the conversion into harmless compounds to be at its optimum rate. Use of catalytic converter, although still new in Malaysia, proved to release Pt and Rh particles into our environment [6].

Heavy metals including Cu, Zn, Pb and Ni are among the commonly used elements in automobile industries, either as the main element for parts or components fabrication in a vehicle or as additives such as in lubricants for engine operation. An example use of heavy metals is in spark plugs. The demanded criteria for a spark plug are for it to be long lasting and capable of igniting in any condition. Thus, Cu is the element commonly used as electrode in spark plugs as it is able to fulfil all of the demanded criteria. Other elements used as spark plugs electrode are Pt, Pd, Ir, Au, Ni and W [7]. Cu compounds is also used in lubricants as anti-wear agent by providing a protective layer on engine surfaces to reduce friction and prevent damages due to continuous rubbing between engine parts.

Lead compounds, particularly lead tetraethyl $(C_2H_5)_4Pb$, are known to be effective additive in fuels as antiknock agent. Use of such compound however, ends up leaving an enormous amount of lead oxide, a very toxic metal, into the environment. This set out the effort, by petroleum companies to find alternative additive of the same effectiveness, which results in the use of unleaded fuels. In this type of fuels, agents such as MTBE, benzene and toluene, having better ability to boost octane number in fuel replaces the use of lead compounds as antiknock agents [8]. Later, enforcement of MTBE, benzene and toluene as antiknock agents took place immediately following the affective of Clean Air Act 1990 [9]. Full use of unleaded fuels however, does not put to stop the use of lead compounds in motoring activities. This compound could still be detected in the environment, fortunately in a smaller amount owing to its use as anti-wear agent in lubricant oils for engines [10].

Use of lubricant oil requires periodical changes after an engine has covered a certain mile to guarantee a long lasting engine lifespan. The lubricants, which function is to smooth each component movements as well as prevent damages by creating a layer of oil on engine surfaces, should have the ability to provide protection even under great pressure. Among of the alternative additives added into lubricant oils having all the abilities needed for a lubricant to perform are zinc compounds. Zinc dialkyldithiophosphate (ZDDP) is an agent, which provides additional protection under extreme-pressure or in a heavy-duty performance situation. Its other functions are to protect the lubricant itself from oxidative breakdown and to prevent the formation of deposits in engines [11, 12].

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Aside from being use as electrode in spark plugs, Nickel is also used for plating the outer part of a vehicle such as tyre rims [13, 14]. It is also one of the elements used to fabricate a special alloy for plating surfaces of cylinders and pistons of an engine. The plated surfaces does not only became long lasting but also resistant to high heat, thus providing a very good platform for heat conductivity as well as offers resistance from damages and scratches [15].

Formation of deposits in engine system is another cause for release of traffic-related elements into the environment. Residue from burning fuel will leave an amount of soot, which in turn stain the engine system, while rubbing of metal surfaces will eventually cause erosion and wearing, leaving metallic and soot particles to accumulate in the engine oil. Oil filter should be able to clean engine oil from all adsorbed deposits and residues before it is recycled. Continuous operation and formation of deposits though, will eventually clog the filter. Additional to that, engine oil will undergo thermal and mechanical degradation as well. Clogging of filters, degradation of engine oil and improper maintenance of engine will cause more deposits build-up, lowering engine's efficiency, and increasing the demand for fuel consumption. Excessive soot, particles and dust released by an engine will also clog other part of the engine system such as catalytic converter, mufflers etc. Aside from that, clog formation will create high pressure that eventually causes further damage to other part of the system and the release of more microscopic particles into the environment [16, 17].

t is undeniable that certain heavy metals, such as Cu, Zn and Ni are required by our body to maintain a good health. Biological demand for these elements however, is in trace level and unnecessary entry of these elements at a high concentration from the environment into any biological system will cause adverse health effects. On the other hand, elements of the platinum group (PGE) such as Pt and Rh are not needed by the body to maintain its natural functions. Existence of such elements in any biological system: human, animals or plants, however does happen either through a deliberate introduction, such as for medical reasons in human or through contamination of the environment, in animals and plant. A deliberate exposure of platinum compounds, such as carboplatin and cisplatin, in human is for chemotherapies due to its ability to retard cancer cell [18, 19].

Schäfer et al. 1998 have classified several heavy metals according to its mobility properties. He observed that mobility properties of Pb is the lowest, followed by Cu, Ni and lastly by Zn. Zn has the highest mobility and is the easiest to be transferred from one medium to another. The mobility ability of platinum group elements was reported in the order: Pd > Pt ≥ Rh [18, 19]. With the mobility properties, it is important to be aware of the poisoning factors possess by each element. Table 1 summarizes several adverse health effects that are brought by these elements following overexposure. It is therefore, the objective of this study is to determine the concentration of six selected elements of traffic activities origin, in road dust samples from selected sampling sites.

Table 1: Adverse health effects of overexposure of Pt, Rh, Cu, Zn, Pb and Ni

Elements	**Health effects of overexposure**	**Reference**
Platinum (Pt)	DNA alterations Cancer Allergic reactions of the skin and mucous membrane Damage of organs, such as intestines, kidneys and bone marrows Lungs irritations and breathing difficulties	[19, 20]
Rhodium (Rh)	Highly toxic and carcinogenic	[21]
Zinc (Zn)	Skin irritation Anaemia	[23]
Nickel (Ni)	Allergy reactions such as skin rashes (mainly from jewellery) Irritant contact dermatitis	[24]
Lead (Pb)	Anaemia Damage of kidneys and brain cells Miscarriage and subtle abortions Disruption of nervous system Behavioural disruptions of children such as aggression, impulsive behaviour and hyperactive	[25, 26]

Material and Methods

Sampling location and methods

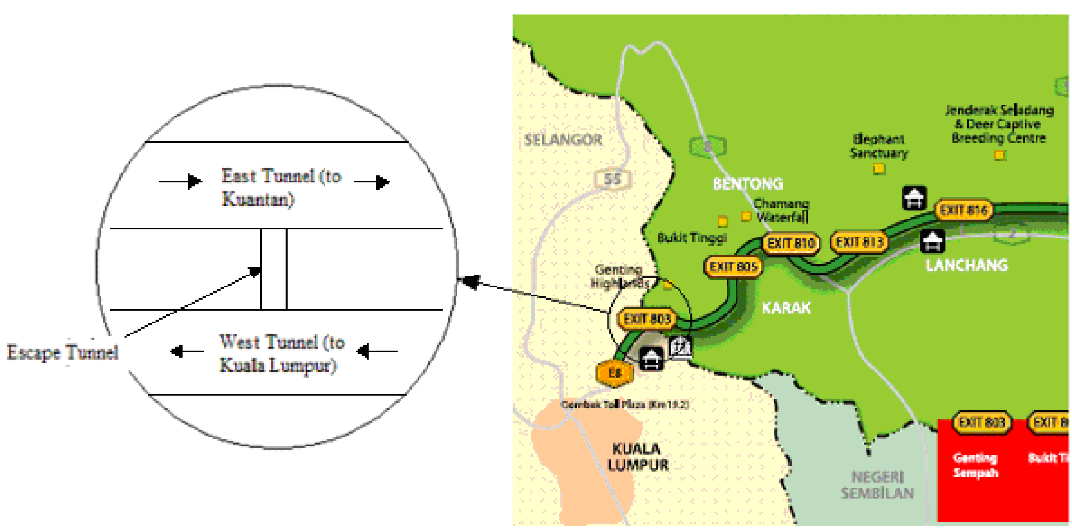

Figure 1: Layout diagram and location of Genting Sempah Tunnel

Genting Sempah Tunnel, located in Genting Sempah, Bentong, is one of the oldest tunnels built in Malaysia. It consists of two tunnels, to the west and east peninsular of Malaysia, each with two lanes with the length of 1 km each (Figure 1). The tunnel, which is situated at the Karak-Kuala Lumpur highway, is a busy location with traffic activities especially on holidays. All vehicles using Karak-Kuala Lumpur highway en route to East Coast must use this tunnel and vice versa. The high density of vehicles that pass through the tunnel requires the tunnel to be cleaned and maintained monthly. Table 2 shows the statistics of vehicles using the Genting Sempah Tunnel for year 2006.

Table 2: Statistics of vehicles using Genting Sempah Tunnel (Bentong East Toll Plaza) for year 2006

Month	**Type of Transportation**		**Total (unit)**	**Daily Average**
	Light-weight	**Heavy-weight**		
January	806868	103315	910183	29360.7
February	612877	97771	710648	25380.3
April	651535	113518	765053	25501.8
May	697354	120702	818056	26388.9
June	722369	118879	841248	28041.6
July	674682	120701	795383	25657.5
August	753580	125310	878890	28351.3
September	640661	120654	761315	25377.2
October	883185	101309	984494	31757.9
November	635518	124158	759676	25322.5
December	853643	118429	972072	31357.2
Average	**721115.6 ± 92367.0**	**114976.9 ± 9679.7**	**836092.5 ± 90585.7**	**27499.7± 2446.4**

Source: Lembaga Lebuhraya Malaysia (Malaysian Highway Authority) 2007

The concentration of Zn, Cu, Pb, Ni, Pt and Rh in road dust samples of Genting Sempah Tunnel was determined monthly, for a one year-period. Genting Sempah Tunnel was selected as sampling site, with assumptions that emissions, dusts and particles from its traffic activities will remain trapped in the tunnel. Samplings of the road dusts were carried out between the 20th and 25th of each month, starting from January 2006 until in December 2006 except for March. Three sampling points each were selected along East Tunnel (to Kuantan) and West Tunnels (to Kuala Lumpur), whereas four points were selected in Escape Tunnel. A range of 1 – 2 kg of road dust samples were collected from each sampling point. The road dust was collected by brushing the walls and floors at each collection point of the tunnel using plastic brushes. Samples obtained were kept in polyethylene containers, labelled and ready to be transported to laboratory for analysis.

Sample digestion and analysis

In the laboratory, all road dusts samples were sieved to obtain desired size (<425 µm), homogenized and kept in airtight plastic bottles to prevent interaction with moisture and air. Aqua regia solution was used to digest the samples, where 8 ml of aqua regia solution was added to 2 gm of road dust sample. The mixture was swirled slowly and left for a few minutes until bubbles from the acid reactions cleared. The samples were then heated nearly to dryness. The residue was added with 10 ml of 2% nitric acid and diluted with deionised water to a volume of 50 ml. All digestion procedures were done in fume hood. This final solution was then sent for analysis using Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES) to determine its element content. Mixed standard solutions of desired metals: Zn, Cu, Pb, Ni, Pt and Rh, were prepared fresh from stock solutions before analysis for calibration and qualitative purposes.

Result and Discusions

Zn, Cu, Pb, Ni, Pt and Rh content

The results of Zn, Cu, Pb, Ni, Pt and Rh analysis in road dust samples are given in Tables 3, 4 and 5. As expected the Zn, Cu, Pb and Ni monthly concentrations in road dust samples were found to be higher than the concentration of Pt and Rh. These elements are expected to be more in concentration due to the ware and tear of vehicle parts that being made or involving these element, whereas Pt and Rd are only expected being release from the catalytic converter alone [27]. The concentrations of elements found in this study are in the order of: Zn > Cu > Pb > Ni > Pt > Rh. Results in Table 3, 4 and 5 shows that only Zn and Pb shows obvious difference in monthly concentration among the three tunnels. The monthly average concentration of Zn in escape tunnel was 2886.1 ± 1251.6 µg/g, as compared to monthly average of 1457.9 ± 513.8 µg/g and 1316.3 ± 797.3 µg/g for West and East tunnels respectively. However for Pb, the monthly concentration was found to be higher in road dust samples collected in West and East Tunnels road dust samples than the monthly concentration in Escape Tunnel. In West and East Tunnels, the monthly average concentrations for Pb were 179.1 ± 64.3 µg/g and 164.6 ± 51.8 µg/g respectively whereas the monthly concentration for escape tunnel was 123.2 ± 27.0 µg/g. Monthly average concentrations of Pt, Rh, Cu and Ni did not show any obvious difference in concentration between the three tunnels studied.

The effects of traffic volume

The monthly average concentration of the six elements was plotted against the monthly traffic density of the Genting Sempah Tunnels and presented in Figures 2, 3 and 4. Results of the study show that the monthly average concentrations of the elements in this study remain in the same range despite higher traffic density recorded in January, October and December. For example, the Zn monthly concentration in the West Tunnel road dust samples were 1406.5 ppm, 1340.1 ppm and 889.7 ppm for January, October and December respectively as compared to the monthly average of 1457.9 ppm. Therefore this study indicates that the elemental monthly average concentrations of these elements did not affected by the changes of the traffic density in the tunnel. The same trend could be observed for February, April, September and November, which have the lowest traffic volume for year 2006. The concentration of the six elements determined does not decrease with the traffic density for all four months.

Table 3: Average concentration of selected elements in road dust samples of Genting Sempah Tunnel (West Tunnel).

Month	**Average concentration (µg/g)**					
	Zinc (Zn)	**Copper (Cu)**	**Lead (Pb)**	**Nickel (Ni)**	**Platinum (Pt)**	**Rhodium (Rh)**
January	1406.5 ± 2.5	180.2 ± 2.0	148.7 ± 4.6	30.6 ± 2.3	0.1 ± 0.03	2.0 ± 0.4
February	1490.0 ± 3.3	110.6 ± 1.3	131.2 ± 4.6	19.8 ± 0.6	2.6 ± 0.1	0.8 ± 0.1
April	2400.8 ± 5.6	252.6 ± 2.5	194.4 ± 9.5	29.9 ± 1.1	6.2 ± 0.3	4.5 ± 0.5
May	2052.3 ± 5.3	223.0 ± 1.0	162.1 ± 2.3	23.2 ± 1.6	5.7 ± 0.4	2.1 ± 0.1
June	1628.0 ± 1.8	359.9 ± 9.7	269.4 ± 6.4	24.3 ± 1.4	5.3 ± 0.1	3.4 ± 0.1
July	1630.7 ± 2.7	353.3 ± 5.3	272.1 ± 4.4	27.0 ± 2.3	4.2 ± 0.3	2.5 ± 0.1
August	1638.0 ± 12.7	355.9 ± 2.4	276.8 ± 4.6	33.6 ± 2.2	5.4 ± 0.1	3.5 ± 0.1
September	625.6 ± 4.6	121.7 ± 1.2	133.9 ± 6.7	12.3 ± 0.6	7.5 ± 0.5	3.1 ± 0.1
October	1340.1 ± 93.9	175.6 ± 4.8	124.3 ± 4.1	16.5 ± 1.6	6.9 ± 0.2	3.2 ± 0.4
November	935.2 ± 1.9	172.9 ± 2.6	104.5 ± 1.6	28.1 ± 2.1	6.7 ± 0.5	1.0 ± 0.02
December	889.7 ± 3.7	158.7 ± 2.2	152.7 ± 3.9	17.4 ± 0.9	6.9 ± 0.1	0.9 ± 0.03
Monthly average	1457.9 ± 513.8	224.0 ± 93.7	179.1 ± 64.3	23.9 ± 6.7	5.2 ± 2.2	2.5 ± 1.2
Monthly range	625.6 – 2400.8	110.6 – 359.9	104.5 – 276.8	12.3 – 33.6	0.1 – 7.5	0.8 – 4.5

Table 4: Average concentration of selected elements in road dust samples of Genting Sempah Tunnel (Escape Tunnel).

Month	Average concentration (µg/g)					
	Zinc (Zn)	**Copper (Cu)**	**Lead (Pb)**	**Nickel (Ni)**	**Platinum (Pt)**	**Rhodium (Rh)**
January	418.1 ± 2.5	166.4 ± 3.2	165.9 ± 2.6	24.4 ± 0.4	1.0 ± 0.1	1.2 ± 0.3
February	3761.9 ± 9.7	266.1 ± 1.5	114.4 ± 4.8	26.1 ± 0.8	2.8 ± 0.02	1.5 ± 0.1
April	4049.1 ± 8.6	256.6 ± 2.4	135.6 ± 3.5	27.7 ± 1.0	5.5 ± 0.3	4.8 ± 0.1
May	4020.5 ± 7.6	292.9 ± 1.4	146.2 ± 5.3	28.1 ± 1.1	10.3 ± 0.6	1.3 ± 0.04
June	3741.2 ± 10.3	305.3 ± 1.9	135.0 ± 2.8	27.7 ± 1.0	7.9 ± 0.03	3.0 ± 0.1
July	3743.9 ± 6.3	303.8 ± 2.7	137.7 ± 4.2	30.4 ± 3.5	5.1 ± 0.1	3.0 ± 0.1
August	3751.2 ± 8.6	306.9 ± 1.4	142.4 ± 3.1	37.0 ± 1.0	6.2 ± 0.3	3.2 ± 0.2
September	1488.5 ± 3.8	104.3 ± 0.6	112.4 ± 6.4	11.9 ± 1.4	4.8 ± 0.1	1.2 ± 0.02
October	2168.4 ± 5.1	169.6 ± 0.9	86.2 ± 0.5	13.1 ± 1.3	9.0 ± 0.2	0.7 ± 0.1
November	2935.4 ± 8.5	152.8 ± 1.2	101.7 ± 0.6	15.3 ± 1.3	6.2 ± 0.4	1.7 ± 0.04
December	1668.6 ± 6.5	133.0 ± 0.6	78.0 ± 3.2	14.6 ± 1.7	5.3 ± 0.3	1.4 ± 0.1
Monthly average	2886.1 ± 1251.6	223.4 ± 78.3	123.2 ± 27.0	23.3 ± 8.3	5.8 ± 2.6	2.1 ± 1.2
Monthly range	418.1 – 4049.1	104.3 – 306.9	78.0 – 165.9	11.9 – 37.0	1.0 – 10.3	0.7 – 4.8

Table 5: Average concentration of selected elements in road dust samples of Genting Sempah Tunnel (East Tunnel).

Month	Average concentration (µg/g)					
	Zinc (Zn)	**Copper (Cu)**	**Lead (Pb)**	**Nickel (Ni)**	**Platinum (Pt)**	**Rhodium (Rh)**
January	2646.5 ± 8.3	293.9 ± 3.2	271.0 ± 3.7	34.0 ± 0.4	1.1 ± 0.02	2.3 ± 0.2
February	1521.9 ± 3.9	109.0 ± 0.6	117.9 ± 5.0	21.0 ± 1.1	2.1 ± 0.1	1.0 ± 0.1
April	1859.1 ± 3.5	183.7 ± 0.5	156.0 ± 8.5	28.4 ± 2.3	9. 3 ± 1.2	6.7 ± 0.2
May	2519.2 ± 7.3	242.2 ± 1.2	168.2 ± 0.6	22.2 ± 1.0	9.4 ± 0.5	2.3 ± 0.1
June	435.5 ± 3.3	163.0 ± 1.4	115.0 ± 2.0	11.5 ± 1.7	7.8 ± 0.4	5.0 ± 0.4
July	438.1 ± 1.9	166.0 ± 1.9	117.7 ± 3.4	14.2 ± 1.2	4.5 ± 0.2	3.2 ± 0.3
August	445.3 ± 3.5	169.8 ± 0.5	122.4 ± 3.7	20.8 ± 1.1	5.8 ± 0.2	4.0 ± 0.2
September	683.7 ± 1.9	133.7 ± 0.5	143.2 ± 0.6	15.0 ± 0.8	7.7 ± 0.6	3.2 ± 0.1
October	1515.9 ± 3.7	198.1 ± 0.9	174.9 ± 1.0	34.7 ± 2.3	7.7 ± 0.3	4.6 ± 0.1
November	1339.0 ± 9.6	241.2 ± 1.4	182.8 ± 1.2	28.0 ± 1.8	7.1 ± 0.4	0.8 ± 0.04
December	1074.9 ± 3.4	212.4 ± 0.9	241.6 ± 0.9	26.9 ± 1.0	7.7 ± 0.2	1.5 ± 0.2
Monthly average	1316.3 ± 797.3	192.1 ± 53.1	164.6 ± 51.8	23.3 ± 7.8	6.4 ± 2.7	3.1 ± 1.8
Monthly range	435.5 – 2646.5	109.0 – 293.9	115.0 – 271.0	11.5 – 34.7	1.1 – 9.4	0.8 – 6.7

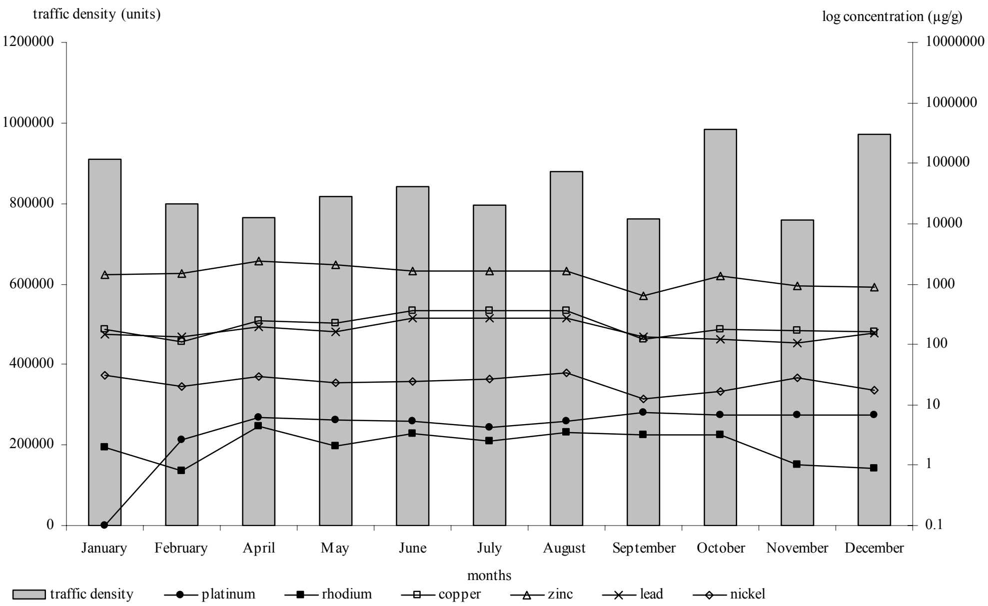

Figure 2: Monthly average concentration of Pt, Rh, Cu, Zn, Pb and Ni of West Tunnel with monthly traffic density for year 2006

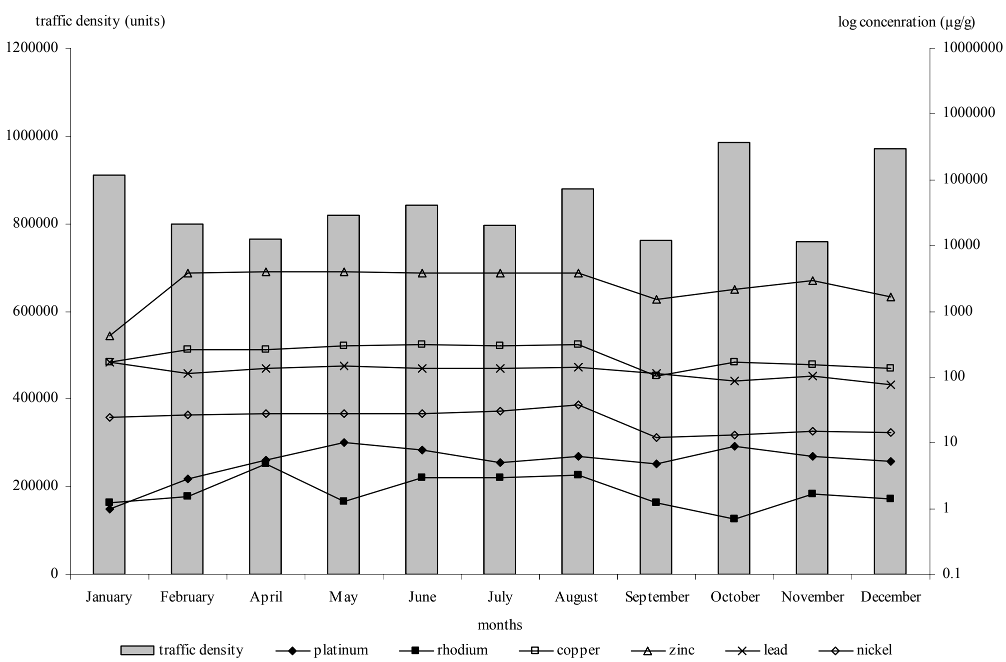

Figure 3: Monthly average concentration of Pt, Rh, Cu, Zn, Pb and Ni of Escape Tunnel with monthly traffic density for year 2006

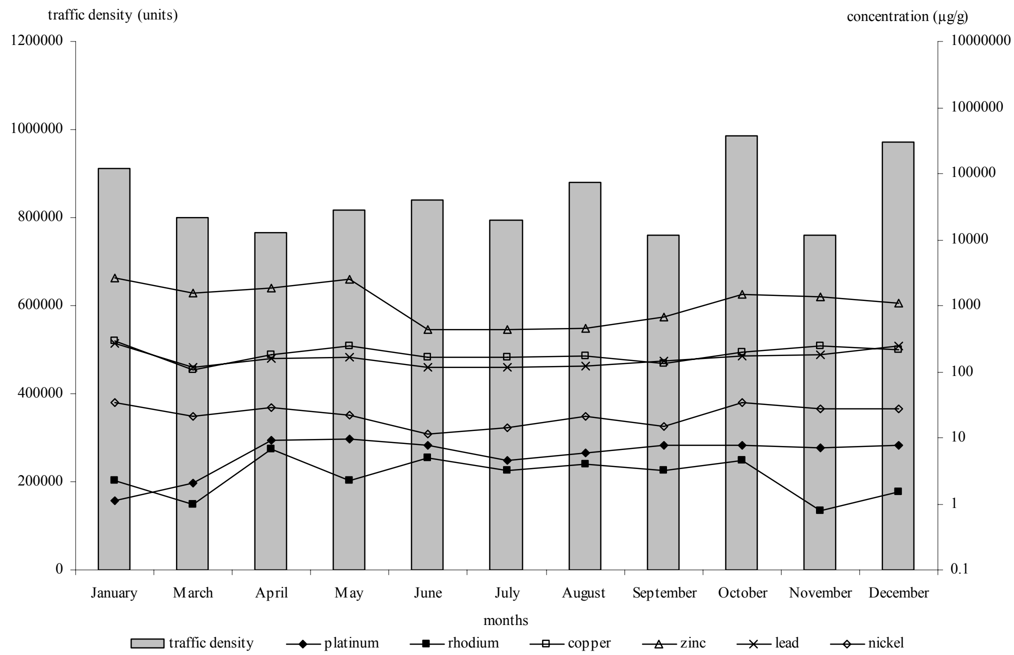

Figure 4: Monthly average concentration of Pt, Rh, Cu, Zn, Pb and Ni of East Tunnel with monthly traffic density for year 2006

Emissions of heavy metals into the environment, caused by traffic activities have always been an interest subject to be studied. The result of this study is compared with reported study by other researches for both close and open sampling sites as presented in Table 6.

Table 6 shows that the monthly average concentration of Cu and Zn determined in this study were 10 and 15 times higher respectively compared to the same element found in open Auckland Motorway, New Zealand. The concentration of Cu and Zn determined in road dust samples from Auckland Motorway are found to be 22 µg/g and 130 µg/g respectively. The same situation could be seen in the road dust samples of Beltsville, USA open system, where the concentration of Zn was reported to be 4.7 µg/g. However, the concentrations of Pb and Ni in road dust samples from Beltsville were found to be higher than the concentration of same elements determined in this study. In Beltsville's road dust samples, Pb concentration was found to be 522 µg/g and 172 µg/g for Ni. Environmental factors such as wind, rain and runoff water are important factors for the element distribution patterns observed in open sampling sites [3].

For close sampling sites, Table 6 shows that the monthly average concentration of Pt (5.8 ± 0.6 µg/g) and Rh (2.6 ± 0.5 µg/g) in this study were higher than results reported in Austria. However, the same monthly concentration range were observed for Cu and Zn from both study i.e. 188 ± 3 µg/g and 1360 ± 30 µg/g, for Austria study and 192.1 ± 53.1 µg/g and 1316.3 ± 797.3 µg/g for this study respectively.

On the other hand, the concentrations of Pb and Ni in road dust samples from Austria were reported to be higher than the concentration Pb and Ni determined in this study. As can be seen in Table 6, the monthly Pb and Ni concentration in theirs study were 783 ± 15 µg/g and 152 ± 2 µg/g whereas the concentration of Pb and Ni determined in our study were 155.6 and 23.5 ppm respectively. The results in Table 6 also shows that our elemental concentration were higher that a study reported in Geležinis Vilkas Tunnel in Republic of Lithuania where the Cu, Zn and Pb determined were found to be 81 ± 15 µg/g, 112 ± 29 µg/g and 67 ± 9 µg/g respectively.

Table 6: Pt, Rh, Cu, Zn, Pb and Ni concentration in road dust samples of various studies

Sampling site system	**Sampling location**	**Vehicle daily average (unit)**	**Elements concentration (µg/g)**						**Ref.**
			Zn	**Cu**	**Pb**	**Ni**	**Pt**	**Rh**	
Open	Auckland Motorway, New Zealand	10000 – 19000	130	22	780	60	*nr	nr	[13]
Open	West of U.S., near Plant Industry Station, Beltsville	20000	4.7	nr	522	172	nr	nr	[14]
Open	West of southbound lanes, Washington-Baltimore Parkway, Bladensburg	48000	7.4	nr	540	162	nr	nr	[14]
Open	South Sweden	nr	54.0 – 870.0	9.1 –510.0	10.0 – 200.0	4.7 – 37.0	nr	nr	[28]
Close	Geležinis Vilkas Tunnel, Vilnius City, Republic of Lithuania	nr	112 ± 29	81 ± 15	67 ± 9	nr	nr	nr	[29]
Close	Tanzenberg Tunnel ventilation shaft Austria (Styria)	nr	1360 ± 30	188 ± 3	783 ± 15	152 ± 2	0.05	0.01	[30]
Close	Tanzenberg Tunnel ceiling Austria (Styria)	nr	nr	nr	nr	nr	0.06	0.009	[31]
Close	Genting Sempah Tunnel, Pahang, Malaysia	25000 – 30000							This study
	West Tunnel		1457.9 ± 513.8	224.0 ± 93.7	179.1 ± 64.3	23.9 ± 6.7	5.2 ± 2.2	2.5 ± 1.2	
	Escape Tunnel		2886.1 ± 1251.6	223.4 ± 78.3	123.2 ± 27.0	23.3 ± 8.3	5.8 ± 2.6	2.1 ± 1.2	
	East Tunnel		1316.3 ± 797.3	192.1 ± 53.1	164.6 ± 51.8	23.3 ± 7.8	6.4 ± 2.7	3.1 ± 1.8	
	Average		**1886.7 ± 868.3**	**213.2 ± 18.2**	**155.6 ± 29.0**	**23.5 ± 0.3**	**5.8 ± 0.6**	**2.6 ± 0.5**	
	Occurred naturally in soil	-	64	12	14	8			[13]
							0.02	0.003	[32]

*nr – not reported

The results of this study also shows that the concentrations of six elements determined in the road dusts samples were higher than the concentration of the same elements occurred naturally in soil as shown in Table 6. Thus, this indicate that the traffic activity may contribute to the increment of these elements and further more the sampling location was very far from any urban or industrial activities.

Conclusions

The concentrations of Zn, Cu, Pb, Ni, Pt and Rh have been successfully determined in the road dust samples of Genting Sempah using the ICP-OES. The monthly average concentration of the elements are 1886.7 ± 868.3 µg/g, 213.2 ± 18.2 µg/g, 155.6 ± 29.0 µg/g, 23.5 ± 0.3 µg/g, 5.8 ± 0.6 µg/g and 2.6 ± 0.5 µg/g Zn, Cu, Pb, Ni, Pt and Rh, respectively. Results show that only Zn and Pb indicate obvious difference in monthly concentration among the three tunnels. The Pb monthly concentration was found to be higher in road dust samples collected in West and East Tunnels road dust samples than the monthly concentration in Escape Tunnel. The monthly average concentrations of Pt, Rh, Cu and Ni did not show any obvious difference in concentration between the three tunnels studied. Since the sampling location was far from any urban and industrial areas, the higher content of elements related to traffic found in the road dust samples may due to the traffic activities.

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