Qualitative and Quantitative Study of Heavy Metals in Runoff of Highways of Tehran

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Key Words**:** Runoff, highway, heavy metals, water pollution, traffic

ABSTRACT

Environmental pollution of soil, plants and deposits around highways endanger urban environment through heavy metals as the by-products of vehicles and urban industries along with other pollutants. In this research, three main highways of Tehran city; namely *Shahid Chamran*, *Shahid Hemmat* and *Yadegar Emam* which had the highest rate of vehicle transportation were selected and required sampling was performed in various distances and specific spots. After preparation of the sample by applying standard method, the concentration of 5 metals such as; lead, cadmium, nickel, zinc and copper were measured by means of atomic absorption spectrophotometer–flame absorption. The TSS, TS, sodium and potassium contents were measured as well. The results showed the presence of maximum zinc contents ranging from 0.86 to 5.85 mg l^{-1} and lead contents of 0.6 to6.5 mg/l, both as the highest metal contents in the three highways. On the other hand, the average concentration of total heavy metals found in the highways were measured for the 5 metals and showed the degree of pollution in Chamran highway, with 3.294 mg/l zinc, 3.06 mg/l lead, 0.210 mg/l copper, 0.127 mg/l nickel and 0.058 mg/l cadmium concentrations. Nevertheless, the heavy metals concentration in Hemmat highway had the minimum amount. It seemed that the high degree of pollution in Chamran highway is due to very heavy and lengthy traffic in this highway, since it is located in the central part of Tehran. It also joins northern part of the city to the downtown area and tolerates a heavy traffic jam of vehicles. In addition, due to the slow traffic move and long stops in Chamran highway, tires undergo more abrasion due to repeated brakes and this intensifies, zinc discharge and lead releases from automobile fuels, all of which are being factors that lead to an increase in the metals contents of runoffs of Chamran highway. The aforementioned subject matters reveal urban management's need to arrange for more controlled and coordination in traffic, environmental preservation and hygiene, particularly in the urban highways.

INTRODUCTION

The industrial development and the fact that most sewage and runoff penetrate into water or soil have caused an increase in the environmental pollution with heavy metal pollutants, all acting as a threat to today's world. Therefore, it is a requisite to classify and identify the sewage in terms of their specifications so that a proper method of purification and treatment can be handled, aiming to decrease the risks for environment, living creatures and aquatics(6). In environmental term, heavy metals are attributed to metals such as chromium and cadmium, which are toxic substances to living organisms(15,17). Highways are sources of the arrival of lead in the environment and the acceptor waters and lead, an additive to gasoline as an anti-oxidant is exhausted from consumed gasoline vehicles act as one of the most important pollutants for atmosphere, soil, plants and water. According to study, 80% of total lead in the atmosphere (the figure reaches to 97% in some reports) is generated from the above-mentioned sources (12,22). Further studies show that the lead contents along roadsides are in direct correlation with the size of traffic (1,16,20). Thus, a qualitative study and knowledge on highway runoffs as well as measuring their heavy metals contents can be of high importance. There is a variety of pollutants in the highways,
such as vehicles and urban industries, bridges, parking lots and other impenetrable surfaces, garbage, constructional waste materials, tires abrasion, pesticides, plastic bags, etc. (9) The runoff carry the pollutants into lakes, rivers and other receiving waters, where they act as a risk to aquatics and cause their death. Pesticides, herbicides and chemical fertilizers usually enter into water through city parks and green sites, often enter into runoff by water flows and rain, leading to algae growth and eutrophication. (5, 7, 9) There are many questions on runoffs collection, their treatment and purification and highway factors that can be of economical and environmental value (5, 18). The law on abrasion control, runoffs deposits, roads and highway was passed in 1972 and an Act pertaining to adjustment in the coastal region was presented in 1990 and the promotion program, particularly to control runoffs and coastal waters have already been suggested (8, 21). The Environment Preservation Agency (EPA) has developed some guidelines for the management, particularly for measuring non-point coastal

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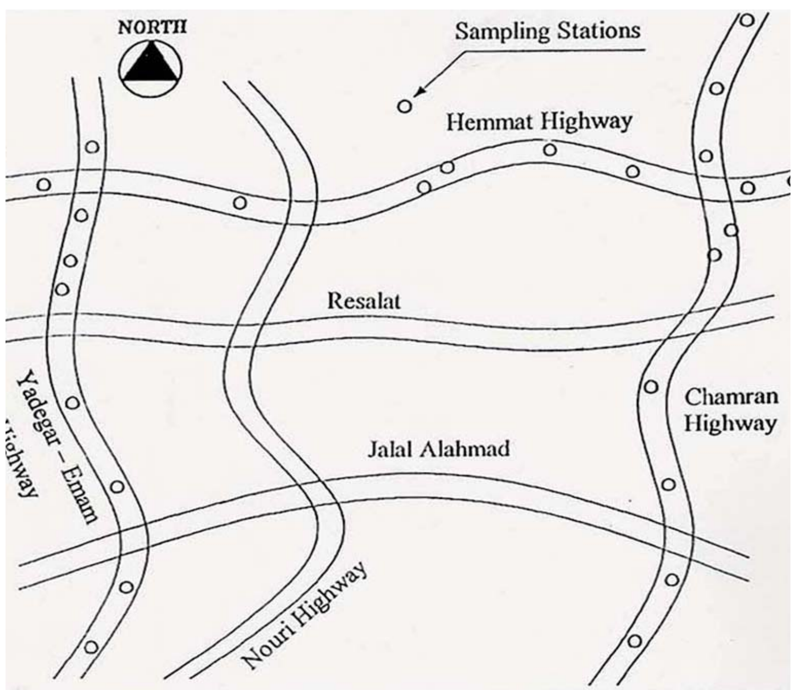
pollutant sources. The guidelines are supposed to be executed in the coastal regions to achieve highest degree of runoff controls. They include best application of management, technology process, utilization agenda and procedures to utilize roads, bridges and highways aiming in their pollution control (8, 11).

Heavy metals, oils, construction wastes and traffic-generated pollutants have potentials to be absorbed in soil and transferred to the lakes and rivers through runoffs (3,8). Aromatic poly-cyclics of three-ring hydrocarbons (PAH·s) are extensively observed in fine sands while six-ring molecules with maximum concentration are found in fine silt sections. In addition, the chemical properties of $PAH_{,s}$ particles have an important role in their reactivity. Pollutants distribution and transfer, their relationship with organic and inorganic substances and size of different particles are very important, for first particles move and are transferred with different sizes and various hydrolic position, second organic substances are decomposable and subsequently, their pollution is of biodegradable type. Third, the bed-living organisms with optional nutrition are able to choose smaller particles with more organic substances (2, 19).The size of deposits is one of the important factors of heavy metals accumulation, where there is an inverse relationship between suspended heavy metals concentration and particle diameters in runoffs and deposits, while, the relationship is not clearly specified for $PAH_{,s}$; smaller three-ring molecules of such compounds, like florin, fenanthren and antracen are mostly accumulated in fine sand section and six-ring molecules accumulate in fine Silti sections. These compounds include indnosi piren, benzoji piren, dibenzo Antracen. PHA,s molecules are able to solve and leave the system during movement (2, 4, 10, 13). In order to control pollution of water system, source of particles should be controlled and prevent their entry into rivers through transportation, optional transfer and temporary reserve of particles (14, 19).

Map 1. **Runoff sampling stations and highway locations in Tehran**



MATERIALS AND METHODS

Samples were taken from runoff of Chamran, Hemmat and Yadegar Emam highways in the center of Tehran city during snow and rainfalls season in February and March 2001 (map 1).

Samples were taken in duplicate form and from determined places, as shown in Figure I. The spots were selected based on the geographic location, sensitivity of earth shape and having more water flow.

Sampling stations

1) Shahid Chamran highway , after Janshid Abad bus stop;
2) Shahid Chamran highway , under Gisha bridge;
3) Shahid Chamran highway , lower than Park Way gas station;
4) Shahid Chamran highway , behind university complex area under watch tower;
5) Shahid Chamran highway , after university complex, autobahn notch (right direction);
6) Shahid Chamran highway, after university complex, autobahn notch(left direction);
7) Shahid Camran highway, near Modiriyat bridge;
8) Shahid Chamran highway, under Modiriyat bridge walkway;
9) Shahid Chamran highway, after Modiriyat bridge; .
10) Hemmat highway, Hemmat and Park Way bridge;
11) Hemmat highway, before Park Way bridge (Emam Sadegh University Complex);
12) Hemmat highway, before Yadegar Emam bridge;
13) Hemmat highway, before Fazlollah highway;
14) Hemmat highway, after Fazlollah highway;
15) Hemmat highway, after Fazlollah highway (left direction);
16) Hemmat highway, after Park Way bridge;
17) Hemmat highway, Vanak Park area;
18) Yadegar Emam highway, beginning of bridge;
19) Yadegar Emam highway, before Golafshan cross road;
adegar Emam highway, intersection of Hemmat and adegar Emam highways;
21) Yadegar Emam highway, end of Yadegar Emam bridge , before Karadj autobahn;
22) Yadegar Emam highway, after second exit of Fazlollah autobahn;
23) Yadegar Emam highway, after Karadj autobahn cross road (Tarasht area);
24) Yadegar Emam highWay, approximately 500 meter lower than sample;
25) Yadegar Emam highway after Hemmat Bridge.

Standard method through nitric acid digestion was used to measure heavy metals of runoffs. To do so, 100 ml sample, the pH of which has been reached below 2 by nitric acidification, was poured in Erlen 250cc after agitation and was heated under hood to decrease its volume to around 15-20 ml through evaporation. After this stage, 5ml-concentrated nitric acid was added to the samples and the samples were then heated till their volume reached to 15ml. The same procedure was repeated in three stages and at the end, brown steam resulted from the concentrated nitric acid evaporation was observed. After the stages, the samples were passed through Wattman No. 42 and their volume was increased to 100 ml by using distilled water. The samples were then stored in plastic dishes. In the final stage, concentration of metals was read through flame atomic absorption instrument. Sodium and potassium concentration was measured and tested by flame photometry unit while TSS and TS were measured through gravimeter method.

Next step was to determine and measure solvent heavy metals of runoffs. To perform the test, a given volume of acidified sample was passed through Wattman No. 42 after agitation. 100 ml of the solution collected by filter was poured in Erlen 250ml and went under digestion process by using high concentration nitric acid in the hood. At the end, the solution was passed through filters for lead, nickel, cadmium, zinc and copper and the numbers were read through atomic absorption spectrophotometery. The findings are listed in the relevant tables.

RESULTS

Table 1 gives the results obtained form runoff analysis taken for heavy metals form Shahid Hemmat, Shahid Chamran and Yadegar Emam. The results show that heavy metals had maximum concentration in Chamran highway and zinc, lead and copper are of frequent heavy metals in the runoffs collected from this highway. Similar tests were performed for zinc, lead, copper, nickel and cadmium solutions. The results of analysis have been given in Table 2. The findings reveals that among the entire metals found in Chamran highway, zinc is the highest and cadmium is the lowest amount; while lead has maximum concentration for both highways. The Table also shows that concentration of heavy metals solution in the samples approximate to their total amount, showing higher limits of metals as solved in the highway runoffs. Table 3 shows concentration of TS, TSS, sodium and potassium obtained from the analyses of runoff samples. The high difference between TS and TSS shows the percentage of solids in the above-mentioned solutions. There is a sub-relation between accumulation of suspended heavy metals and size of particles. Snowfall during sampling and salty spray have lead to increase in sodium amount in some samples. This influences in the fluidity and movement of heavy metals and thus questions the efficiency of sand and sedimentation purification for runoffs.

Figures 1 and 2 show concentration of the total and solved heavy metals for copper, lead, zinc, cadmium and nickel. According to this , zinc and lead have higher concentration in runoffs. Figure (3) compares the degree of lead and zinc metals in total figures and solvent. The trivial difference in their figures shows their presence in solvent phase. Figure (4) expresses Ts, Tss, Na and K concentration in gram per liter, showing high difference in Ts concentration in various substations. Figures (5 and 6) show concentration of total and solvent heavy metals in the highways; respectively, showing higher concentration of those metals in Shahid Chamran highway.

DISCUSSION

The analysis of results showed highest concentration of total heavy metals were as follows: zinc with 0.86mg/l to 5.85 mg/l range and an average concentration of 2.449 mg/l had highest range concentration, lead coming next with a range of 0.6 mg/l to 6.5 mg/l and an average concentration of 2.276 mg/l. The average concentration of the heavy metals in the three highways under study showed the intensity of pollution in Chamran highway where the average total metals found in that highway consisted of: zinc (3.924 mg/l), lead (3.06 mg/l), copper (0.21 mg/l), nickel (0.127 mg/l) and cadmium (0.058 mg/l). Their concentrations in Yadegar Emam were: 1,862 mg/l, 2.075 mg/l, 0.157 mg/l, 0.115 mg/l and 0.048 mg/l; respectively. There was less concentration of the mentioned metals in Shahid Hemmat highway than the other two highways. It seemed that pollution load in Shahid Chamran was more than the other two highways. The pollution was due to the density and high degree of traffic. In the meantime, the distances between intersections were shorter in Chamran highway, resulting in occurrence of slow traffic, repeated stoppage of car, more abrasion of asphalt, tire and brake lent, which lead to discharge of zinc, nickel and lead metals in the environment, increasing concentration of those metals in runoffs. By comparing the results for total metals and metals solved in runoff it can be concluded that metals in runoffs were mostly solvable and there was not much difference among them. This showed that the metals were present in solution phase. Increase in sodium in some samples was due to salt spray for snow melt since there was snowfall during and before sampling, sodium concentration had increased in runoff and this leads to an increase in fluidity and movement of heavy metals in winter time. The results obtained from TS and TSS measurement showed some fluctuation in TS contents ranging from 0.85 mg/l to 21/7 mg/l . This might be due to melting speed of snow in different sampling stations as well as traffic density. With respect to high concentration of heavy metals in runoffs and in view of the fact that there have been many reports from across the world regarding possibility of arrival of runoffs in acceptor and underground waters and taking this in to account that studies carried out in Germany and the Netherlands showed the presence of high amounts of PAH,s in runoffs, this should be noticed that aggregation of those pollutants can lead to environment, acceptor water and underground water pollution, affecting man's health or the aquatics death. Thus, directing runoffs to surface waters and/or lack of proper management in control or purification causes the entry of sediments with heavy metal contents to the acceptor waters which harm aquatics through interference in their growth, perspiration and reproduction and as a result, they endanger surface and underground water sources and environments through increase in the concentration of heavy metals as well as PAH,s contents and might lead to death of aquatics and problems in resources and water quality managemen.

Table 1. **Concentration of total heavy metals in the highway runoffs of Tehran (mg/l)**

Sampling Stations	Cu	Pb	Zn	Cd	Ni
1	0.32	6.5	4.04	0.1	0.16
2	0.38	4.1	5.8	0.05	0.19
3	0.19	2.3	5.85	0.09	0.13
4	0.19	2.3	4.5	0.06	0.05
5	0.13	0.64	2.4	0.028	0.14
6	0.19	1.38	2.7	0.029	0.103
7	0.35	5.6	4.95	0.08	0.19
8	0.18	2.9	2.55	0.04	0.17
9	0.05	1.9	2.53	0.05	0.11
10	0.12	1.9	1.4	0.04	0.03
11	0.146	1.4	2.6	0.045	0.18
12	0.07	0.6	1.7	0.03	0.14
13	0.08	1.5	0.86	0.04	0.03
14	0.18	2.2	1.5	0.03	0.06
15	0.11	2.1	1.35	0.045	0.07
16	0.07	1.9	1.8	0.03	0.095
17	0.08	1.8	1.3	0.05	0.11
18	0.17	2.3	2.1	0.09	0.19
19	0.08	2.3	1.64	0.04	0.09
20	0.19	2.4	2.1	0.06	0.13
21	0.14	2.6	2.13	0.05	0.18
22	0.26	1.5	2.05	0.06	0.105
23	0.15	2.0	1.8	0.03	0.052
24	0.14	1.9	1.73	0.03	0.14
25	0.13	1.6	0.9	0.03	0.04

Table 2. **Concentration of dissolved heavy metals in the highway runoff of Tehran (mg/l)**

Sampling Stations	Cu	Pb	Zn	Cd	Ni
1	0.26	4.5	2.56	0.08	0.11
2	0.33	3.6	5.5	0.05	0.15
3	0.16	2.2	5.62	0.04	0.11
4	0.14	1.84	4.2	0.045	0.03
5	0.11	0.6	2.1	0.024	0.12
6	0.165	1.0	1.8	0.019	0.089
7	0.25	5.5	3.68	0.07	0.15
8	0.15	2.3	1.72	0.03	0.13
9	0.04	1.6	2.1	0.03	0.08
10	0.03	1.2	1.28	0.02	0.02
11	0.12	0.84	2.5	0.04	0.14
12	0.05	0.6	1.6	0.01	0.09
13	0.03	0.7	0.6	0.015	0.01
14	0.09	1.7	1.1	0.02	0.035
15	0.08	1.4	1.2	0.04	0.03
16	0.06	1.3	1.5	0.03	0.07
17	0.03	1.5	0.76	0.04	0.06
18	0.14	1.8	1.86	0.04	0.16
19	0.02	1.5	1.56	0.032	0.05
20	0.14	1.6	1.97	0.041	0.11
21	0.08	1.8	1.9	0.048	0.13
22	0.162	1.1	1.57	0.027	0.075
23	0.13	1.9	1.4	0.02	0.03
24	0.12	1.3	1.6	0.02	0.08
25	0.11	1.4	0.6	0.02	0.02

Table 3. **Concentration of the (TS, TSS, Na, K) in the highway runoff of Tehran (g/l)**

Sampling Stations	TS	TSS	Na	K
1	1.6	0.912	0.140	0.08
2	6.0	1.141	0.7	0.092
3	2.6	1.135	0.38	0.1
4	2.8	1.172	0.24	0.055
5	1.6	1.131	0.38	0.07
6	3.6	1.147	0.86	0.1
7	3.24	1.128	0.5	0.07
8	2.35	1.179	0.7	0.058
9	8.05	1.141	3.0	0.1
10	1.47	1.14	0.34	0.08
11	10.98	1.142	4.0	0.09
12	6.56	1.151	3.1	0.07
13	11.85	1.155	4.2	0.1
14	1.7	1.11	0.13	0.058
15	2.7	0.90	0.16	0.051
16	2.1	0.82	1.1	0.063
17	6.1	1.83	1.7	0.103
18	21.7	1.153	7.7	0.14
19	4.97	1.152	1.8	0.1
20	4.2	1.134	1.8	0.07
21	3.85	1.123	1.7	0.09
22	2.9	1.141	0.260	0.08
23	1.6	1.143	0.3	0.095
24	2.3	1.162	0.19	0.06
25	5.53	1.125	1.5	0.097

Fig. 1. **Concentration of total heavy metals in runoff of Tehran highways (mg / l)**

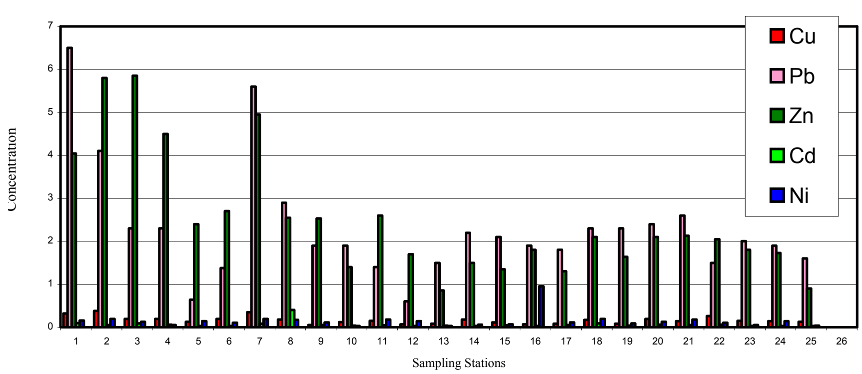


Fig. 2. **Concentration of soluble heavy metals in runoff of Tehran highways (mg / l)**

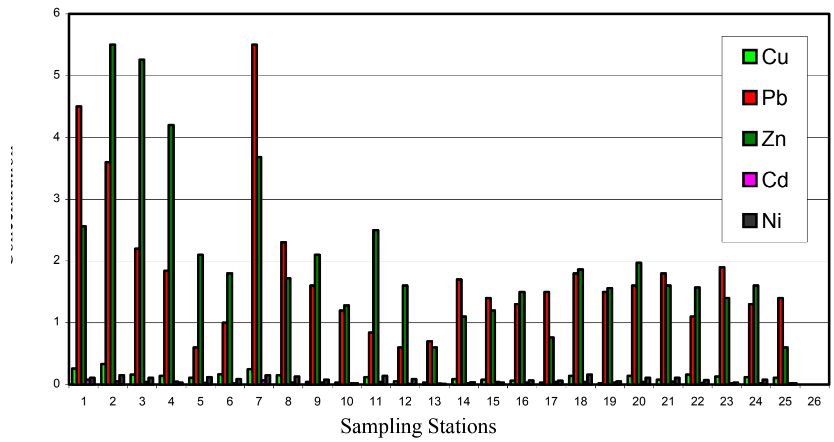


Fig. 3. **Concentration of TS, TSS, Na, K in runoff of Tehran highways (mg / l)**

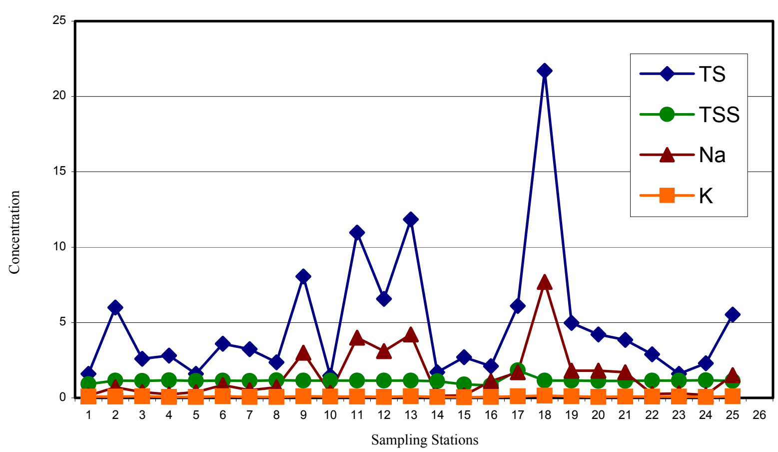


Fig. 4. **Concentration of total and soluble metals of Pb and Ni in runoff of Tehran highways (mg / l)**

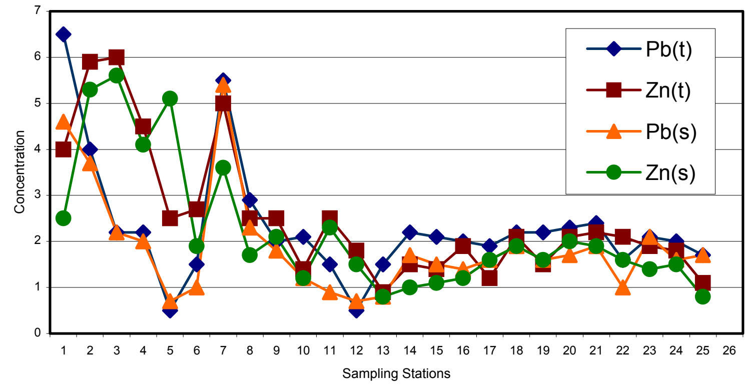


Fig. 5. Average c**oncentration of total heavy metals in runoff of Tehran highways (mg / l)**

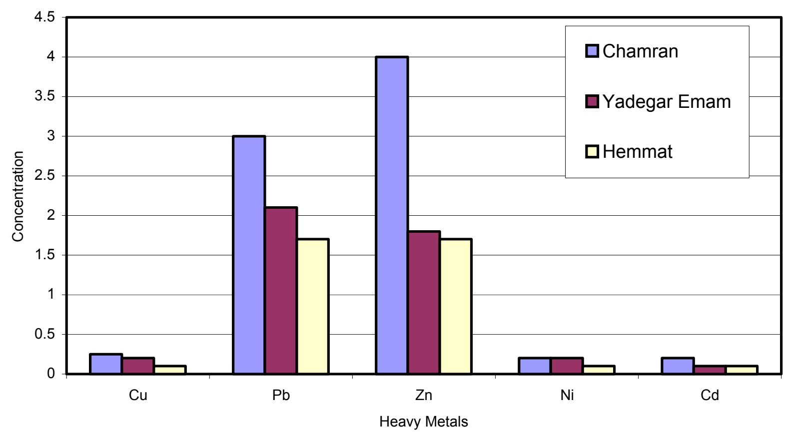
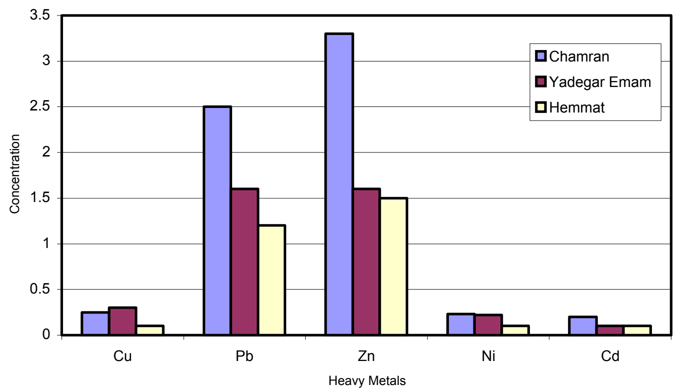


Fig. 6. Average c**oncentration of soluble heavy metals in runoff of Tehran highways (mg / l)**



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