# HEAVY METAL DISTRIBUTION AROUND GOKPINAR SPRINGS, DENIZLI –TURKEY

[1]MAHMUD GUNGOR, [2]ALI KAYA, [3]SUAT TASDELEN, [4]ERDAL AKYOL, [5]ALI AYDIN

[1,2,3,4,5]Pamukkale University
E-mail: mahmud.gungor@deski.gov.tr, alikaya@pau.edu.tr, stasdelen@pau.edu.tr, eakyol@pau.edu.tr, aaydin@pau.edu.tr

**Abstract-** In this study, it is aimed to determine the relation between anthropogenic heavy metal loads in the sediment deposits of the Gokpinar and Derindere drinking water springs and the vertical and lateral magnetic susceptibility distribution in the east of Denizli city center. These springs with average 1,200 m3/s discharges are the most contributing springs to Denizli city center drinking water. We show lateral magnetic susceptibility distribution patterns in the sediment deposits caused by anthropogenic influences in urban areas. MS2D to read all the 346-point samples were taken during the study period. In addition, other parameters that are important in this study of the geology of the point of measurement and the sample taken. Limestones in the upper part of the region due to the sampled points of the mountain, surrounded by a thin, coarse gravel, limestone, containing fragments, sandy, and generally consists of vegetable soil. Heavy metal pollution in the in the sediment deposits of the Gokpinar and Derindere drinking water springs lay waste being discharged to water sources and around. It was showed the pollutant distributions after mapping the data of magnetic susceptibility and showed their sources to assess environmental threats. Magnetic susceptibility method is cheaper and less time-consuming against chemical methods which are taken 30 samples for chemical analysis. We showed that it is enough only using magnetic susceptibility measurements could provide heavy metal pollution distribution in such areas. Maps were generated with data anomalies the resulting and risk areas have been identified. It has been shown that pollution widely if precautions are not taken for a short period of time.

**Index Terms-** Heavy metals, Magnetic susceptibility, Exhaust gas, Pollution, Denizli, Gokpinar, Derindere, Groundwater.

## I. INTRODUCTION

The contamination of urban soils and heavy traffic soils in cities by developing industry is usually high and the most intensive pollution is usually found nearby the biggest industrial centers. Geochemical mapping are usually used for showing the contamination for determining the dimensions of pollution and tracing the sources of pollution. Such as geochemical studies need very much numbers of analyses. It could be used the magnetic susceptibility (MS=χ) measurements to show the amount of the iron-bearing minerals in the material and identify the type of the material. Magnetic susceptibility values of polluted material can be used as a general information of the degree of pollution. Many workers studied to show the magnetic susceptibility measurements for evaluating the degree of heavy metal pollution of soils near the road and industrial areas [1, 2, 3, 4, 5]. Utility of the magnetic susceptibility was shown to be highly effective for investigating industrial pollutants, traffic and other atmospheric pollutants [6, 7]. Many researchers reported that the MS measurements are very useful in investigating industrial discharges and exhaust gases in urban regions [8, 9, 10, 11, 12].

It was confirmed a direct correlation between the magnetic susceptibility of contaminated soils and the presence of hydrocarbons and certain heavy metals such as Pb, Zn, Cr, etc. [13, 14]. The same researchers also used MS measurements to estimate anthropogenic sourced pollution levels of the soils and sediments in urban area [13]. Further, several authors emphasized the value of MS studies in determining heavy metal pollutions in Turkey [5, 15, 16, 17].

We showed the pollutant distributions around of The Gokpinar and Derindere drinking water springs in the east of Denizli city center the traffic roads, after mapping the data of χ and their sources to assess environmental threats in this part of Denizli city, western Turkey. The dimension of heavy metal pollution distribution in district areas around the Antalya-Denizli roads in part of Denizli was showed by using the χ measurements. The aim of this study is to look at the correlation between the χ and heavy metal contamination on collected samples on the sides of the traffic roads and around the drinking water springs. The study on topsoil contamination due to heavy metals was carried out by using the χ measurements near of the roads in this part of Denizli city. We attempted to investigate the correlations between the concentration of heavy metals and the χ from 346 measurement points around of the drinking water springs. The χ contour map based on the topsoil measurements was compiled with a randomly ranged distance density. Some soil samples collected throughout the road sides and residential areas were also analyzed by Atomic Absorption Spectrometer.

Mapping of low frequency magnetic susceptibility (χlf) is a useful method for pollution distribution using the susceptibility measurement meters. The increasing number of motor vehicles and automobiles requires continuous air quality monitoring in large urban areas. This study is a sample of a fast and simple method for analyzing polluted areas of near highways based on χ measurements, which is suitable for

systematic pollution monitoring of extensive areas at low costs and in less time.

The concentration of magnetic particles of anthropogenic originate shown by using the magnetic measurement methods. Researchers were interested in the heavy metal pollution sourced from automobile exhaust and other pollution sources and they showed the amount of trace metals in soils and vegetation near highways and settlement areas [18, 19]. There have been many studies of Pb contamination of soils along highways for the severe adverse health effects and roadside soils may constitute a health hazard if the metals are transferred to other reservoirs [2, 20, 21]. Another study showed obviously that magnetic properties could be beneficially used as a proxy tool in estimating contamination in various pollution sources [22]. It was found out; examined sites with the minimal values of a magnetic susceptibility were connected to heavy traffic activity. Practically all areas of high values of magnetic susceptibility of the soil at the far away from highway were not effected heavy elements. By another study, it was showed the decreases with depth and distance from the roadway for Cu, Pb, and Zn, but that the strongest predictor of metal concentration was the amount of organic matter in the soil, suggesting that individual soil components need to be studied to predict metal behavior [20]. A study showed that the magnetic susceptibility anomalies were related with the soil samples contaminated by Pb sourced by exhaust gases collected near of the highway in Trabzon, Turkey [17]. It was showed that enhancing understanding of the relationship between magnetic properties and heavy metal contents in automobile emission particulates [12]. They aimed at determining the magnetic properties and contents of heavy metals in automobile emission particulates; determining the statistical correlation of various magnetic parameters and heavy metal content; examining further the feasibility of using magnetic susceptibility for pollution assessment. The aim of this study is to examine in side soils of the highways (Denizli, Turkey) in terms of their magnetic mineralogy, and to establish links between enhanced concentrations of anthropogenic magnetic particles, concentrations of Pb, Cu, Ni and Cr which means PLI (The Tomlinson Pollution Load Index).

The Gokpinar and Derindere drinking water springs in the east of Denizli city center “average 1,200 m3/s discharges” are the most contributing springs to Denizli city center drinking water, and these waters do not require any treatment to meet drinking water standards. This area, which has high ground water capacity, also has high earthquake activity. The intense tectonic forces and active faults that control the regional morphology also play a major role in the formation of natural water springs. There are geological units which have differences in lithology, origin and hydrogeology in the drainage basins of the springs. Within these units, whose original characteristics are generally heterogeneous and anisotropic, weak zones and discontinuities have been formed due to the effects of tectonic stresses over time. This discontinuities, hydrogeologically, mean secondary porosity and high permeability and contribute significantly to the groundwater movement, especially near the main faults. The groundwater movement in the basin and the spring yields depend on the size and location of the tectonic discontinuities rather than the primary porosity of the units. Nearly all of the springs in the region are in the "tectonic springs" class. Along the slopes of the mountainous areas within the basin are many large and small springs. The majority of the water springs in the study area are located at the intersection of fault zones. The best examples are Gokpınar and Derindere springs.

The research area is located in the basin of intersection of the Buyuk Menderes and Gediz grabens in the Aegean region, this region has great ground water capacity and high earthquake activity. According to the geographical coordinate system, it covers an area of approximately 10 km2 (Fig. 1). The region is currently experiencing an approximately N–S continental extension. The elevation of the investigation area, which has a rough topographical structure, varies between 580 and 800 meters. The intense tectonic forces and active faults that control the regional morphology also play a major role in the formation of natural water springs ranging from 1 to 1100 l / s. The water springs in this region are the most contributing sources to Denizli city center drinking water.

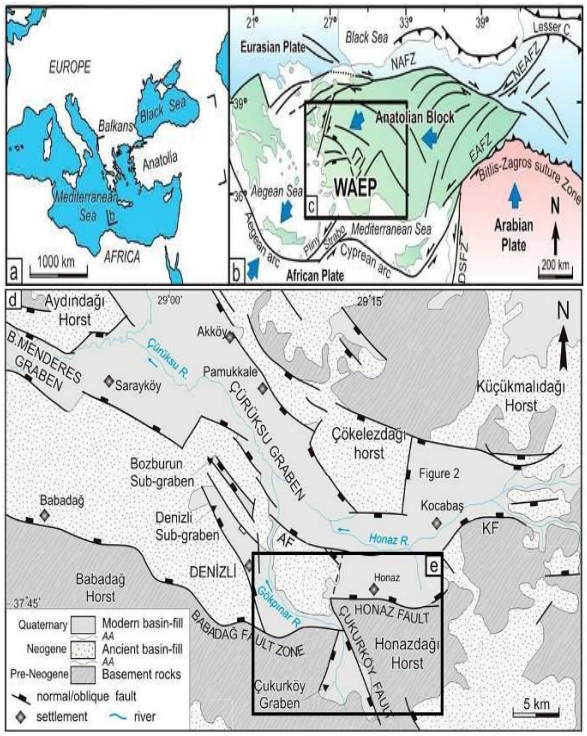


Fig. 1. (a) Tectonic outline of eastern Mediterranean area (compiled from Kaymakci, 2006). (b) Simplified map showing the major active basins in western Anatolia (compiled from Kaymakci, 2006).
Abbreviations: WAEP, West Anatolian Extensional Provinces; DSFZ, Dead Sea Fault Zone; EAFZ, East Anatolian Fault Zone; NAFZ, North Anatolian Fault Zone; DGHS, Denizli Graben Horst System; (d) Simplified Geologic map showing the Denizli Graben Horst System (compiled from Kocyigit, 2005). Abbreviations: AF, Akkale fault; KF, Kaklik Fault [25]. (e) Study Aarea.

This study presents an approach for defining the polluted areas of arounds the two big drinking water supply springs in Denizli. The approach is based on the use of available data and geological, geophysical and hydrogeological field investigation For this purpose, firstly geological features of the region and its immediate surroundings were examined and a geological map (Fig. 2) [24].

Denizli is a very crowded city in Aegean Region, Turkey and the city maybe the most polluted part by anthropogenic activity coming from pollution contamination source and will be the most polluted city at near time. Last fifteen years, there are very economical developments of city, as a result of economic developments, their traffic increased fifteen times from 1995 to now. We aimed to determine the distribution of the heavy metal concentration sourced by exhaust gases and chimney fumes of and around the city. Road samples were collected from near of the heavy traffic road in Denizli, the collected points are shown on Figure 1.

Taken 241 samples from the surface had been collected from surface of the roads in order to use on chemical analysis and laboratory measurements. Anthropogenic sources of pollution basically comprise with especially wastes of automobile exhausts. χ values of these samples were taken by using laboratory measurement system. Samples that were polluted by automobile emission particles were carefully collected from these areas, and to avoid any contamination, the field samples were collected by using plastic scraper.

Then with these values, the contour maps were drawn by using surfer software. Denizli is an inner city located in the eastern Aegean Sea and one of the most populated and industrialized provinces of the Aegean Region. The city center has a population of 450.000 due to 2007 census. Climatic conditions of Denizli are usually hot, whereas higher regions have more severe weather conditions. While summers are hot with scarce rainfalls, winters are rainy and occasionally cold. Average annual temperature is 18°C.

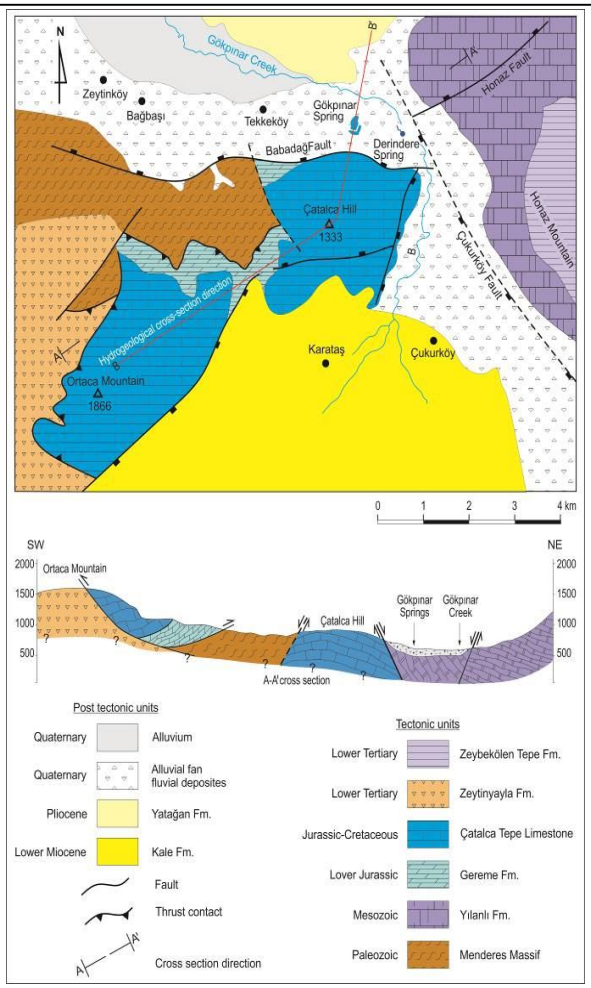



**Fig. 2. Geological map and cross section of the study area (modified from Okay, 1989) [26].**

## II. HYRROGEOLOGY

There are geological units in the drainage basins of the Gokpinar Springs, which are different in terms of lithology, origin and hydrogeology. Within these units, whose original characteristics are generally heterogeneous and anisotropic, weak zones and discontinuities have been formed due to the effects of tectonic stresses over time. This discontinuities, hydrogeologically, mean secondary porosity and high permeability and contribute significantly to the groundwater movement, especially near the main faults. Geological and geophysical studies have shown that the groundwater movement in the basin and the spring yields depend on the size and location of the tectonic discontinuities rather than the primary porosity of the units. Nearly all of the springs in the region are in the "tectonic springs" class.

## III. IMATERIAL AND METHODS

Figure 3 shows that the dots are the position of χ sample points, the location and the terrain maps. Sampling stations were subdivided into two main groups: One of them is west of the study area which is

a very small area due to eastern part. Samples were collected from the depth between 0-20 cm an area of 25 km2 for monitoring geochemical distributions. Each sample of about 0.5 kg was collected from a square of about 10x10 cm. Some of these sample preparations for chemical analysis were carried out in the laboratory of Geology Department, Pamukkale University in Denizli. Some of collected samples were air-dried, desegregated and sieved (small than 2mm) in the laboratory, then they were crushed using a ball mill and prepared for chemical analysis.

The samples were collected from open field, near of the buildings and roads. At the studied area different types of soils occur. The city area of Denizli is covered by carbonatic sandy soils. Because, urban soils are originated by carbonate rocks and the mountains in the southern part of Denizli are limestone units.

To investigate magnetic features of the road surface samples, various kinds of $\chi$ measurements were carried out to laboratory. $\chi$ measurements were carried out by using a MS meter MS2, Bartington Instruments Ltd., linked to MS2B dual frequency sensor. The $\chi$, low frequency magnetic susceptibility ($\chi$lf) and high frequency magnetic susceptibility ($\chi$hf) were measured using a dual-frequency Bartington MS2 magnetic susceptibility meter. Frequency dependent magnetic susceptibility was defined as $\chi fd(\%)=[(\chi lf - \chi hf)/\chi lf]\times 100$, here $\chi$lf and $\chi$hf represent susceptibility values measured at 0.47 and 4.7 kHz, respectively. Collected samples of each data points were measured 3-4 times, in order to check reproducibility and to avoid measurement errors. The error of the measurements of $\chi$ was found to be smaller than 2%, using repeat-measurements. PLI was calculated to examine its correlation with the $\chi$. The linear correlation between the PLI and $\chi$ originally was predicted by [27]. The PLI was used to show how much a sample exceeds the contents of heavy metal background of the natural environments [28]. The PLI which is a result of the contribution of several heavy metals is defined as the root of the multiplication of the concentration factors ($CF_{HMk}$),

$$PLI = \sqrt[n]{\prod_{k=1}^{n} CF_{HMk}} \quad (1)$$

where $CF_{HMk}$ was the ratio of the concentrations of each heavy metal ($C_{HM}$) to the amv which means the mean values.

$$CF_{HMk} = C_{HM} / amv \quad (1)$$

## IV. RESULTS

Fig. 3, 4 and 5 show the sampling locations with faults on google map and topography map, the surfer contour maps of the $\chi$lf, PLI and heavy metal disturbition maps for the surface samples. As illustrated, the $\chi$lf values differ significantly near the road over the study area. It appears that the higher $\chi$lf values are concentrated mostly in sourth of the highway, especially very low north of the the road. Also, in this part of the city is the lowest altitude (Fig. 4). In Figure 4, the high $\chi$lf values are concentrated mostly in the southern and southern-westn parts of the study area and low values of $\chi$ in area are related with the magnetic minerals which may be derived from the traffic emissions. As seen in Figure 4, the low $\chi$ values are found at northern side of the area.

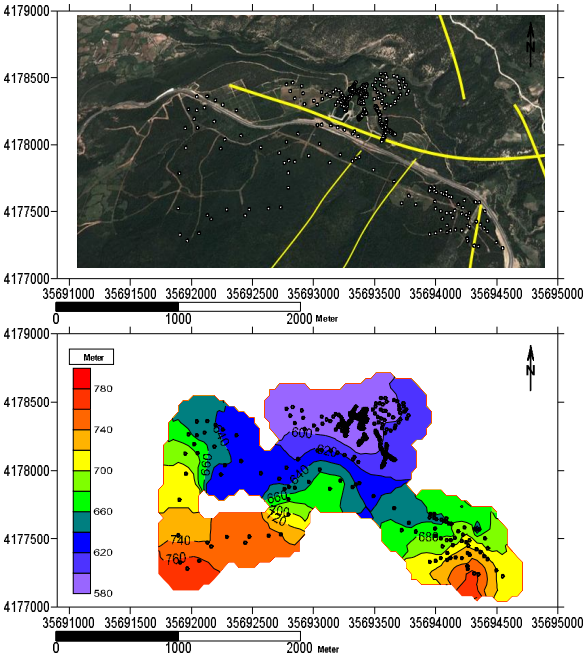



**Fig. 3. The dots show the position of magnetic susceptibility measurements points, the contour maps of magnetic susceptibility.**

Two local anomalies of $\chi$lf are observed on the part of the southeast. In the anomalous zones, $\chi$ increases up to $850\times10^{-8}m^3kg^{-1}$. The highest values occurred in the north part of the city, where mill, machine-building, metal-manufacturing industry and small vehicle repairing shops are located. In the south-eastern part of urban Denizli, relatively high values of $\chi$lf ($450\text{-}800\times10^{-8}m^3kg^{-1}$) were observed near heavy traffic roads. It was seen a relative increase of the susceptibility on the zone of the main roads. The samples from unpolluted areas in the middle, western and south-western parts of the study area yielded $\chi$lf values are very low ($10\text{-}100\times10^{-8}m^3kg^{-1}$).

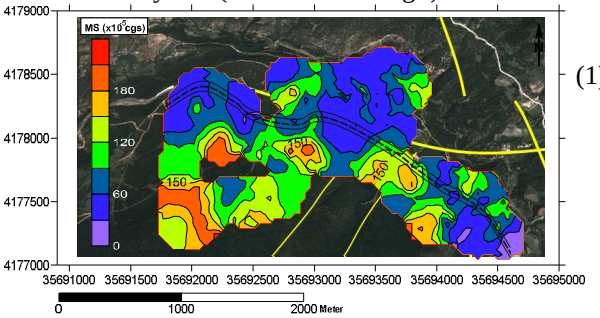



**Fig. 4. Surfer contour map of the $\chi$lf values for the surface samples.**

The contour map of the PLI values is given in Figure 5. The part of the industrial area near the roadshow very high values. These values show that there are many magnetic particle sources of this area. Evaluated distribution of the PLI contour map with the composition of the observed soil samples were mainly controlled by traffic factors.

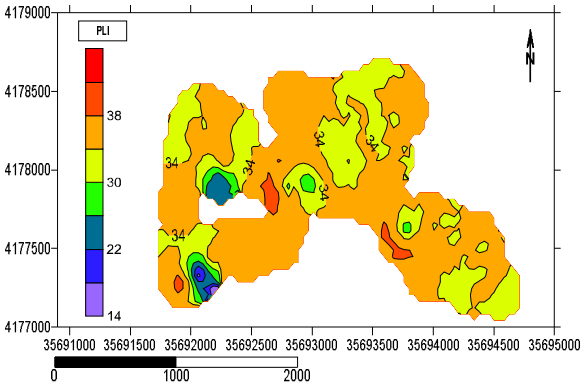
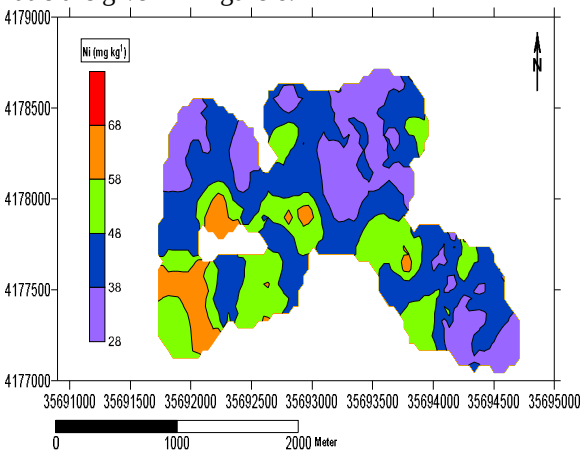



Fig. 5. Contour map of the PLI values for the surface samples. For comparing the results, contour maps of the altitude, χlf, Ni, Pb, Cu, and Cr values for the surface samples were given in the Figure 6. The topography of the area decreases toward northeast. The heavy metal contour maps were related with the susceptibility maps and the topography.

The heavy metal ratios in the soils of north of the area is six times higher than the unpolluted parts. Especially high values element oxide ratios were determined for Pb and Cr. The χhf values were correlated significantly with Cr, Pb, Cu and Ni. Especially Cu and Pb are strongly connected with industrial and exhaust gases contamination of soils. The highest concentration of Ni, Cr, Pb and Cu oxides elements were seen near the major road. Concentrations of Pb are changing from 4 mg/kg up to 26mg/kg, these values are very high and also the other element oxides are very higher in the same part. High anomalies of the χhf correspond with high concentrations of these elements (Figure 5). The χlf versus concentrations of the elements Cr, Pb and Cu ratio are given in Figure 6.



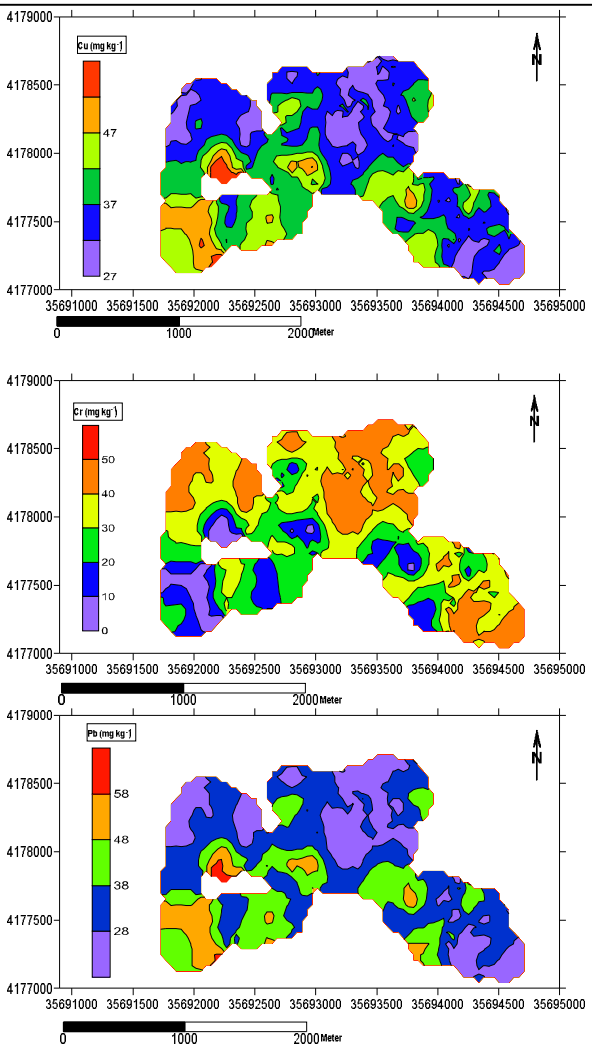
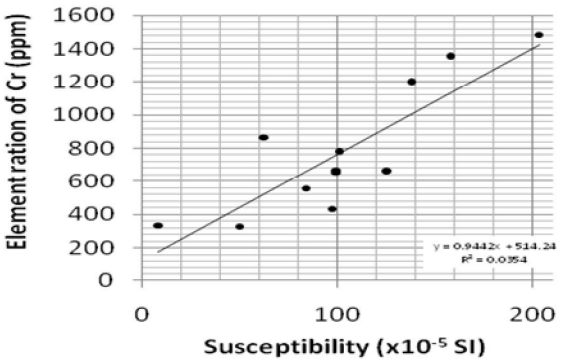
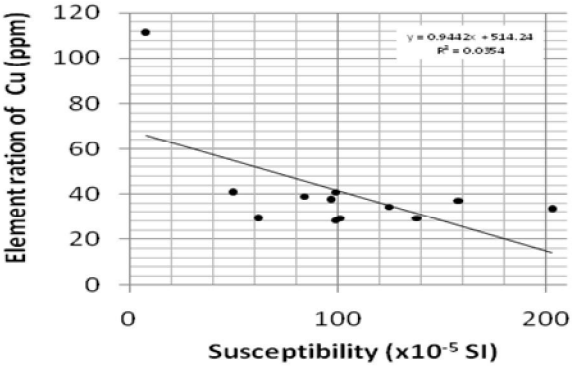




**Fig. 5. Contour maps of the altitude, χhf, Pb, Ni, Cr and Cu values for the surface samples.**



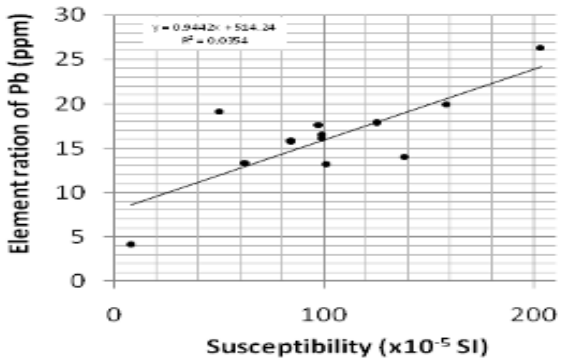



**Fig. 6. The χhf versus concentrations of the elements ratio.**

## CONCLUSIONS

The opportunity of use of a developed method such as χ for an estimation of heavy traffic road was appreciated. Study showed that χ measurements could be used as an express showing the method of the polluted areas of over highway sediments sites. Anomalies in the behaviors of χ values of surface sediments from Denizli-Antalya highway can be interpreted in terms of anthropogenic input. Automobile emission particulates near road soil have relatively high concentrations of magnetic minerals due to PLI. The Tomlinson pollution load index (PLI) shows not much correlation with the χlf.

Magnetic susceptibility and heavy metal element maps gave the distribution of pollution of soils for the appreciation of the environmental situation in such heavy traffic area. The values of χlf give an opportunity to determine heavy metals. χlf contour map of near road correlated with the concentration of heavy metals. Pb, Cu and Ni element oxides are higher in topsoils of below codes the road urban city than high level from the road.

As in-situ data suggest, the magnetic susceptibility values vary on and beneath the road. The variations of the pollution index and the other heavy metals' ratio demonstrate the exhaust gas release which is very effective in the area. The length of the route with heavy traffic in the water spring zone is about 8 km. Roughly 1% of the fuel of the cars has been released as solid waste. This ratio has not been reduced despite the widespread use of unleaded gasoline usage. There are 5 mg and 10 mg sulfur in unleaded and leaded gasoline respectively. Additionally, it includes 1000 ppm ethanol, 100 ppm ethylbenzene, 50 ppm ksilin, 400 ppm propane, 50 ppm toluene. These data suggest that there are considerable amount of heavy metal, nitrite acid and sulfur dioxide release along the route. The level of the pollution can easily be calculated by average vehicle number at Gökpınar ve Derindere springs are.

The Highway Department has been recorded 8262 cars, 743 light commercial vehicles, 187 buses, 2129 trucks and 653 truck-trailers on the daily base and 11975 in total. Recently it will be around 14000 if the annual vehicle increase is 10%. The mentioned route is sloping land which increases the fuel consumption. The total fuel consumption is about 14000 liters/years along the route. It means 140 liters/day or 120 kg/day waste on the route (in the spring's area) is dropped by the vehicles. The annual waste could reach up to 43 tons that is serious for public health.

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