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EXAMINING SOIL POLLUTION OF BÜYÜKÇEKMECE LAKE BASIN USING GEOGRAPHIC INFORMATION SYSTEMS (NORTWESTERN OF TURKEY)

Büyükçekmece Gölü Havzasında Toprak Kirliliğinin Coğrafi Bilgi Sistemleri ile İncelenmesi

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Öz

Hızlı kentleşmenin sonucu olarak birçok antropojenik kaynaktan yayılan ağır metaller toprakların en yaygın kirleticileridir. İnsan sağlığı üzerindeki potansiyel etkilerinden dolayı ağır metal kirliliği, kentleşmenin yoğun olduğu yerlerde, önemli çevre sorunlarından birini oluşturmaktadır. Toprağın kirlenme potansiyelinin belirlenmesi, toprak kaynaklarının kullanımı ve korunması açısından büyük önem taşımaktadır. Bu nedenle bu çalışmada Büyükçekmece Havzası yüzey topraklarında, bakır (Cu), nikel (Ni), Cadmiyum (Cd) ve çinko (Zn) ağır metallerinin mekansal dağılımı ve kirlilik kaynaklarının tespit edilmesi amaçlanmıştır. Çalışma alanından, 2016 yılı Şubat ayında koordinatları önceden belirlenen (rastgele karalej yöntemi) 40 ayrı noktadan toprak örneği alınmıştır. Toprak kirliliği ve mekânsal dağılımlarının belirlenmesinde Coğrafi Bilgi Sistemleri ve mekânsal analizler, son yıllarda en fazla kullanılan yöntemler olduğundan, çalışılan ağır metallerin mekansal dağılımının tespit edilmesinde Coğrafi Bilgi Sistemleri kullanılmıştır. Çalışma sonucunda inceleme sahasının genelinde bakır (Cu), nikel (Ni), kadmiyum (Cd) ve çinko (Zn), konsantrasyon değerlerinin yüksek seviyelerde olduğu gözlenmiştir. Kirleticiler açısından tehlikeli noktalar ise çalışma alanının genelinde tespit edilmiştir. Ancak en yüksek değerler genel olarak çalışma alanının güneyindeki göl çevresinde gözlenmiştir. Bu nedenle çalışma sahası ekolojik risk açısından yüksek riskli olarak değerlendirilmiştir. Büyükçekmece Havzası topraklarında tespit edilen Cu, Ni, Cd ve Zn kirliliğinin kaynağının sanayi kuruluşları ve yerleşmeler ile yakından ilişkili olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Toprak Kirliliği, Büyükçekmece Gölü Havzası, Bakır (Cu), Nikel (Ni), Kadmiyum (Cd) ve Çinko (Zn), Coğrafi Bilgi Sistemleri (CBS)

Abstract

Heavy metals, emitted from many anthropogenic sources, are the most common pollutants in the soil as a result of rapid urbanization. Heavy metal pollution in heavily urbanized areas are one of the important environmental problems due to their potential impacts on human health. Determination of the soil pollution potential is of great importance to utilization and protection of soil resources. Therefore, in this study, it is aimed to determine the spatial distribution of copper (Cu), nickel (Ni), cadmium (Cd) and zinc (Zn) heavy metals and the sources of pollution in the surface soils of Büyükçekmece Basin. 40 soil samples with pre-determined coordinates by systematic random grid sampling method were collected from the study area in February 2016. Geographic Information Systems and spatial analysis, used most frequently in determining soil contamination and spatial distribution in recent years, were used to determine the spatial distribution of heavy metals being studied. As a result of the study, it was observed that the concentration values of copper (Cu), nickel (Ni), cadmium (Cd) and zinc (Zn), were high in the overall study area. Hazardous points in terms of contaminants had been identified throughout the study area. However, the highest values were generally observed around the lake in the south of the study area. For this reason, the study area was considered as highly risky in terms of ecological risks. It was concluded that the source of Cu, Ni, Cd and Zn pollution found in Büyükçekmece Basin soil was closely associated with industrial establishments and settlements.

Keywords: Soil Pollution, Büyükçekmece Lake Basin, Copper (Cu), Nickel (Ni), Cadmium (Cd), Zinc (Zn), Geographic Information Systems (GIS)

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INTRODUCTION

Soils, whose formation take many years and, are one of the natural sources which are mostly unlikely to be renewed, have become one of the most important environmental problems that reach dangerous levels for living creatures as a result of the contamination caused by urbanization and industrialization developed in recent years by the rapidly increasing world population (Hye-Sook et al., 2008; Tomar, 2009; Zhiyuan et al., 2014; Tanrıkulu, 2015). Heavy metals, emitted from many anthropogenic sources as a result of rapid urbanization, are the most common contaminants in the soil (Wu et al, 2009a, 2009b, Wu et al., 2010; Wu et al., 2011). They are metals with a density higher than 5 g / cm^3. In this group, there are 60 metals including Lead, Cadmium, Chromium, Iron, cobalt, copper, nickel, zinc, molybdenum, vanadium, aluminum, arsenic, tin, and manganese , (Li et al., 2004; Yuebing et al., 2010; Rodriquez Salazar et al., 2011; Montinaro, 2012; Sofianska et al., 2013). The heavy metals causing contamination by accumulating in the soil are chromium (Cr), Nickel (Ni), lead (Pb), arsenic (As), zinc (Zn), copper (Cu) and cadmium (Cd) (Türkoğlu, 2006; Valladares et al., 2009; Çağlarırmak and Hepçimen, 2010). The excessive use of fertilizers and agricultural chemicals, especially industrial activities, was effective in this distribution (Çağlarırmak and Hepçimen, 2010; Uyar et al., 2010).

Many studies have been conducted on the importance of heavy metals since they cause environmental threats by accumulating on the areas where there is intensive urbanization (Sadıklar et al., 1994; Tomar, 2009; Wu at al, 2009a; 2009b; Wu at al., 2010; Uyar et al., 2010; Çağlarırmak and Hepçimen, 2010; Wu at al., 2011; Peker et al., 2012; Taşköprü, 2014; Li et al., 2014; Liu et al., 2014; Bou Kheir et al., 2014; Qing et al., 2015; Freije, 2015; Inboonchuay, 2016; Xu, et al., 2016; Gu et al. , 2016; Tóth et al., 2016; Luo et al., 2016; Liu et al., 2016). However, more emphasis should be placed on the studies both about the conservation of ecosystems and biodiversity as well as about the protection of soils for sustainable development.

İstanbul is one of the cities under the influence of rapid urbanization and industrialization like in many cities that have been under the pressure of intensive settlements and industrialization in the world. The population of the basin also increases in parallel with the population growth in the city. The reason for this is the quality of the new living spaces and the abundance of recreation facilities render the area attractive despite the fact that they are far from the historical, social and economic centers of İstanbul. For this reason, approximately 56 hectares of new settlement areas are being added to Büyükçekmece Basin every year (TMMOB İstanbul European Water Supply Technical Report, 2014). This increase leads to plant, water and soil contamination (Baykal and Erdem, 2003). Agricultural and forest areas have been destroyed in the vicinity of the Lake Büyükçekmece with the increase in construction in the last 10-15 years. While industrial areas increase between Çatalca and Büyükçekmece and on both sides of the road, forest areas have been transformed into agricultural areas and agricultural areas into the areas of settlement (Şenol, 2015; Ç.M.O., 2014; Kurt, 2015). The ecological balance of the basin began to change and the soils in the Büyükçekmece Basin continued to be contaminated as a result of the destruction caused on the basis of this change.

There are two main objectives of this study. First; determination of heavy metal accumulation levels in the Büyükçekmece Basin of İstanbul which is an important settlement area that encounters with intensive industrial contamination. Second; preparing distribution maps of heavy metals especially those that are seen in industrial areas such as zinc (Zn), nickel (Ni), cadmium (Cd) and copper (Cu), identifying factors that cause contamination. After that providing support to ecological studies to be conducted in this area were aimed at in this study.

Study Area

Büyükçekmece Basin, located in the northwest of Turkey, constitutes the study area. This area is situated within the borders of İstanbul Province and is located approximately between 41° 12'58'' parallel north and 28° 35'09" meridian east (Figure 1). Lake Büyükçekmece, one of the most important drinking water resources of İstanbul, is within the boundaries of the basin. While it was previously a lagoon, it became a lake with the filling made in 1988. The area of the basin is 604 km^2.

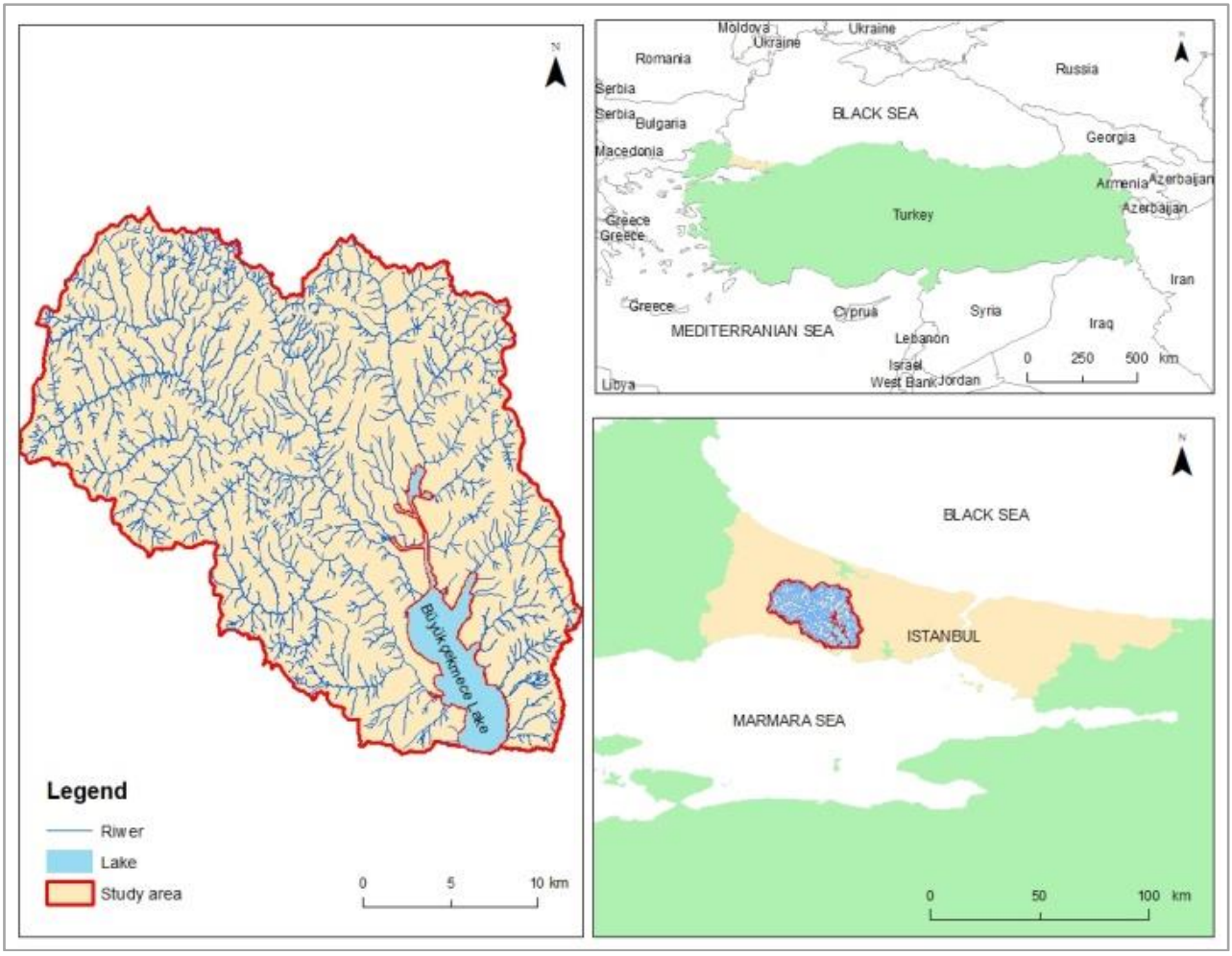

Figure 1: Location Map of the Study Area

MATERIALS AND METHODS

Soil samples were taken from 40 different locations (Figure 2) with predetermined coordinates (by systematic random grid sampling method) located in the study area (Şubat 2016). These samples were collected from a depth of 25 cm because anthropogenic pollutants accumulate in the upper layer of the soil. Geographic Information Systems and geo-statistical methods were used to determine and map the spatial distribution of the heavy metals being studied. The collected soil samples were put and stored in 2 liter plastic bags. The samples were dried within wide filter papers and by covering them with the same papers for 5-6 days in open and clean laboratory environment. In the meantime, the stones and foreign materials inside them were cleaned and the samples were mixed every day using a plastic spoon. The dried soil samples were sieved with the help of 2 mm sieve. Heavy metal analysis in the soil was conducted with ICP-MS device.

ArcGIS Geostatistical Analysis tools were used to determine the laboratory analysis results and spatial distribution of soil samples. The Ordinary Kriging process was preferred in the formation of heavy metal distribution maps. The solution was sought based on the assumption that the regional variables in the Ordinary Kiriking process were stable and the mean was constant. The Indicator Kriging method was used in the spatial prediction and risk assessment. This metod was used to characterize the hazard posed by heavy metal concentrations at s specific threshold value in the study area. Soil quality limit values for zinc (Zn), nickel (Ni), cadmium (Cd) and copper (Cu) were taken into consideration in this method. The Indicator Kriging method was carried out by considering the attribute of the Zn > 150 ppm, Cd >1ppm, Cu >50 ppm, Ni >30 ppm, as point measurements with values 0 and 1 (According Turkey Soil Quality Control Regulation). The indicator kriging technique provides information on the spatial distribution as well as estimates the probability with exceeding threshold values of certain classes (Tarboton vd., 1995; Odeh ve Onus, 2008).

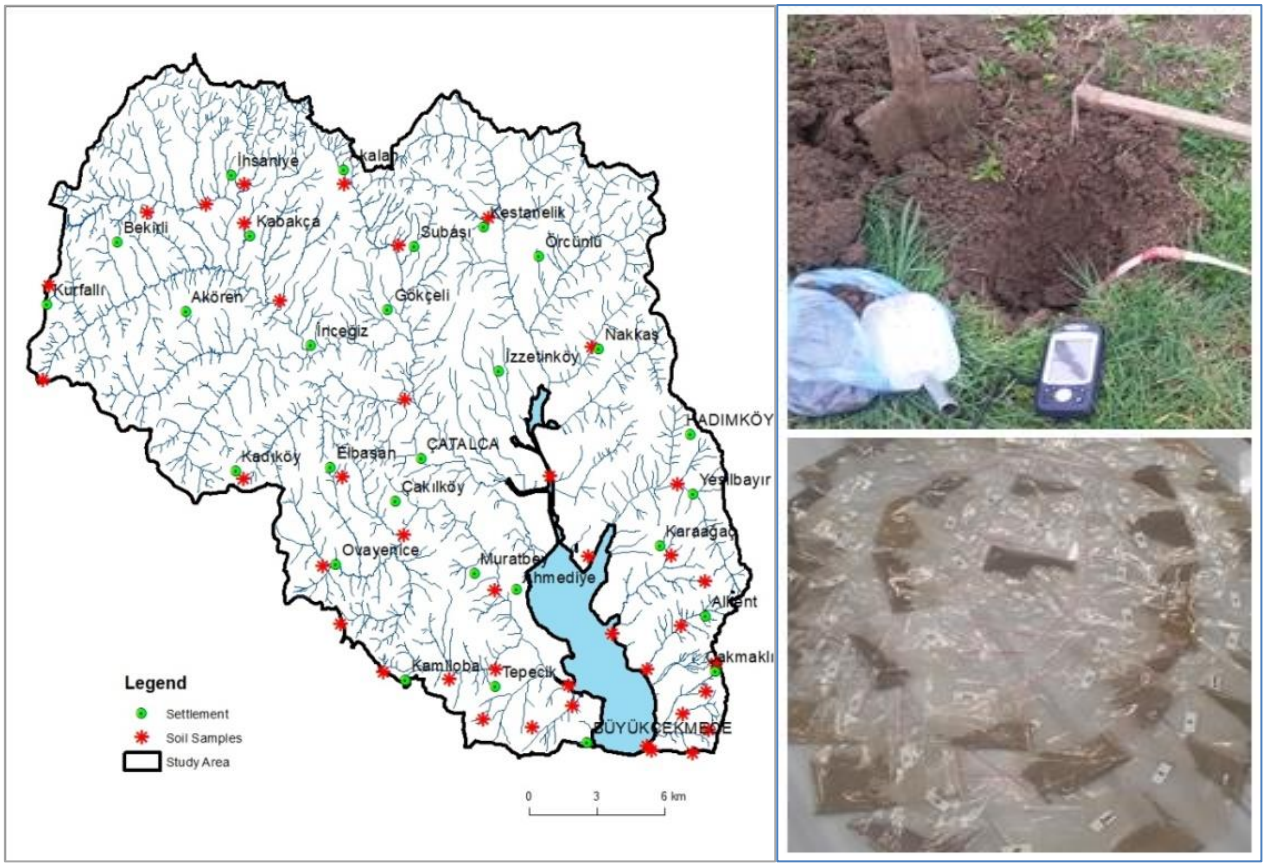

Figure 2: Soil Sample Points in the Study Area

RESULTS

Nickel (Ni) is being used in steel manufacture, galvanizing and electronics industries, cell and battery production, metal coins and steel and food industries (Dağhan, 2011). Serious health problems could be seen when it passes to the human body. It causes destruction in respiratory tubing and dermatological diseases because of its carcinogenic effects (Şener 2010; Zincirlioğlu, 2013).

The spatial distribution of nickel (Ni) in Büyükçekmece Lake Basin during the winter season was shown in Figures 3 and 4. A significant increase was seen in Tepecik, Ahmediye, Muratbey and its north (>182 ppm) as well as in the east of Büyükçekmece Lake (144 ppm) in general when examining the distribution of nickel concentration levels in Büyükçekmece Lake Basin in winter (Figure 3 and 4). When the spatial distribution of the nickel concentration values is examined, it is seen that the values are above the critical value of 30 ppm which is the limit value determined in the Soil Pollution Control Regulation.

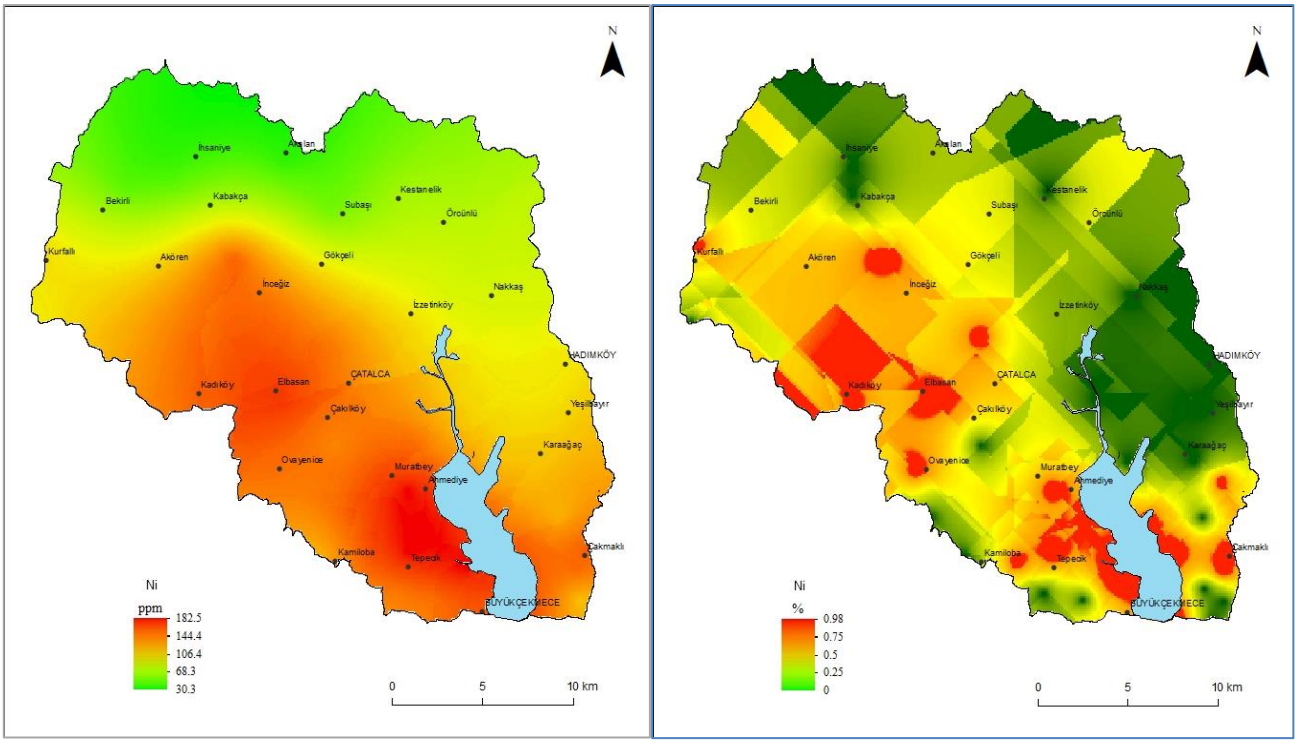

Figure 3 and 4: Nickel (Ni) Concentration of the Surface Soils in the Büyükçekmece Lake Basin and Probability of Ni Values Exceeding 30 ppm

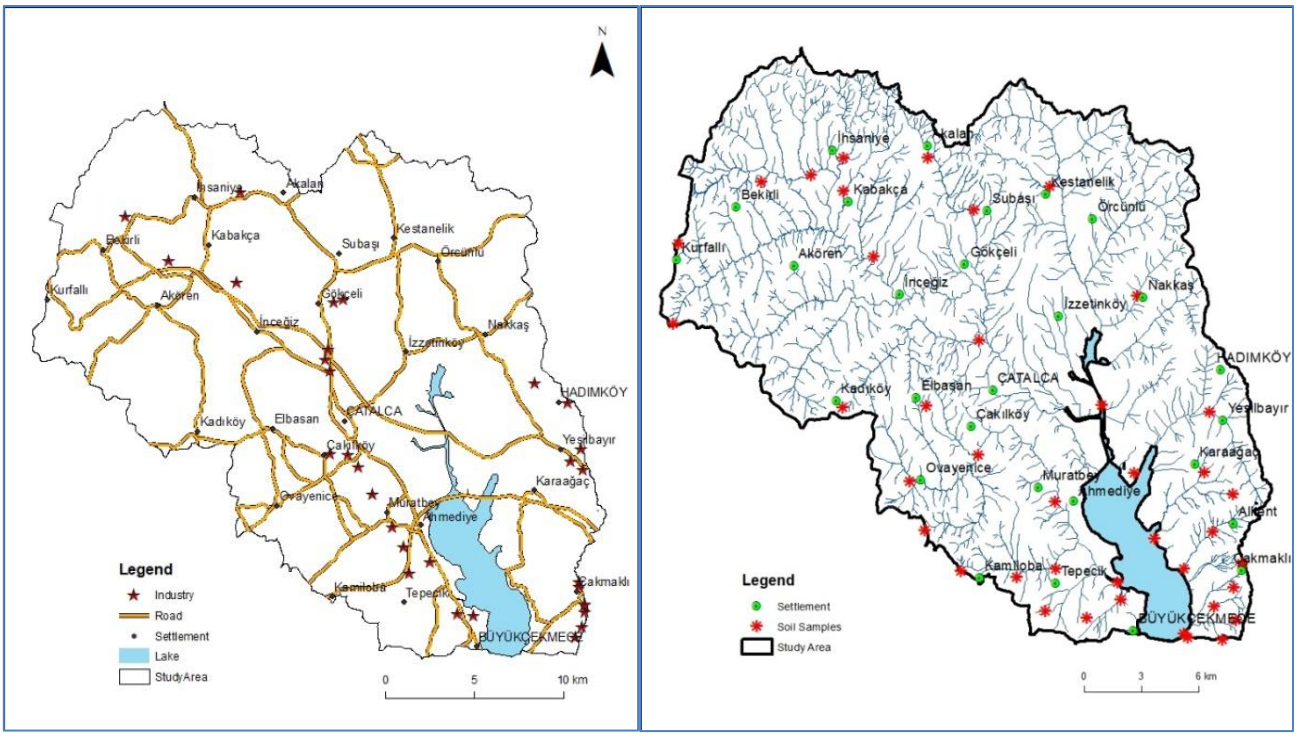

Figure 5: Roads, Residential Areas and Industrial Activities in The Büyükçekmece Lake Basin

The high levels of nickel (Ni) concentration determined arose from the density of industrial establishments and settlements located on the west and east of the Büyükçekmece Lake. It was seen when examining Figures 5 and 6 that industries, roads and surrounding settlements were effective on nickel in the soil.

The possibility of nickel (Ni) contamination in Büyükçekmece lake Basin exceeding the limit of 30 ppm established in the Turkey Soil Quality Control Regulation was also shown in Figures 3 and 4. Areas shown in red color very risky, those

shown in orange color risky, those shown in yellow color medium risky and areas shown in green color constituted low risk regions when examining Figures 3, 4 and 13. Areas with a probability of exceeding the limit value of 50 % in terms of nickel contamination are very risky areas in the Büyükçekmece Lake Basin. Therefore, the close vicinities of the Büyükçekmece Lake are among very risky regions. Other areas are within the risky areas (%51-75) in terms of nickel (Ni) contamination. The area is very risky and risky when the entire study area is taken into account in terms of nickel concentration. The medium risky (%25-50) and low risk (<25%) areas are located in the north of Bekirli, Örcünlü and Yeşilbayır. The existence of high levels of concentration in terms of nickel contamination is due to residential areas and industrial activities (Figures 5, 6 and 13).

Figure 6: The Cement Factory and Residential Areas on the Western Coast of Büyükçekmece Lake

The second element examined in the study area is copper (Cu)**.** Copper (Cu) element is used in pipe, automotive, electronics, pressure systems, power plants and metal coating industries (Karadaş, 2008; Dağhan, 2011; Tonetti et al., 2014). Its excessive accumulation in the body causes a disease called "Wilson's Disease". The symptoms of this disease include nervous system disorders, liver cirrhosis, and formation of color circle in the eye (Dağhan, 2011; Deveci, 2012).

The spatial distribution maps of copper (Cu) heavy metal in winter were shown in Figures 6 and 7. The highest copper concentration values were found in the middle of the Basin (İnceğiz, Elbasan, Kadıköy) and the levels higher than >64.7 were identified around the Büyükçekmece Lake when examining Figure 7 and 8. The high levels of copper in these areas were due to industrial and residential areas. Levels less than about 14 ppm were identified in the north and northern of the study area. The maximum concentration of copper was 64 ppm, while the minimum copper concentration was 14 ppm in the soil samples when considering that the specified limit by the Turkey Soil Quality Control Regulation was 50 ppm. It was seen that it already passed critical levels with regard to copper (Cu) contamination when compared to the maximum copper concentration in the Soil Quality Control Regulation (Figure 7 and Figure 8).

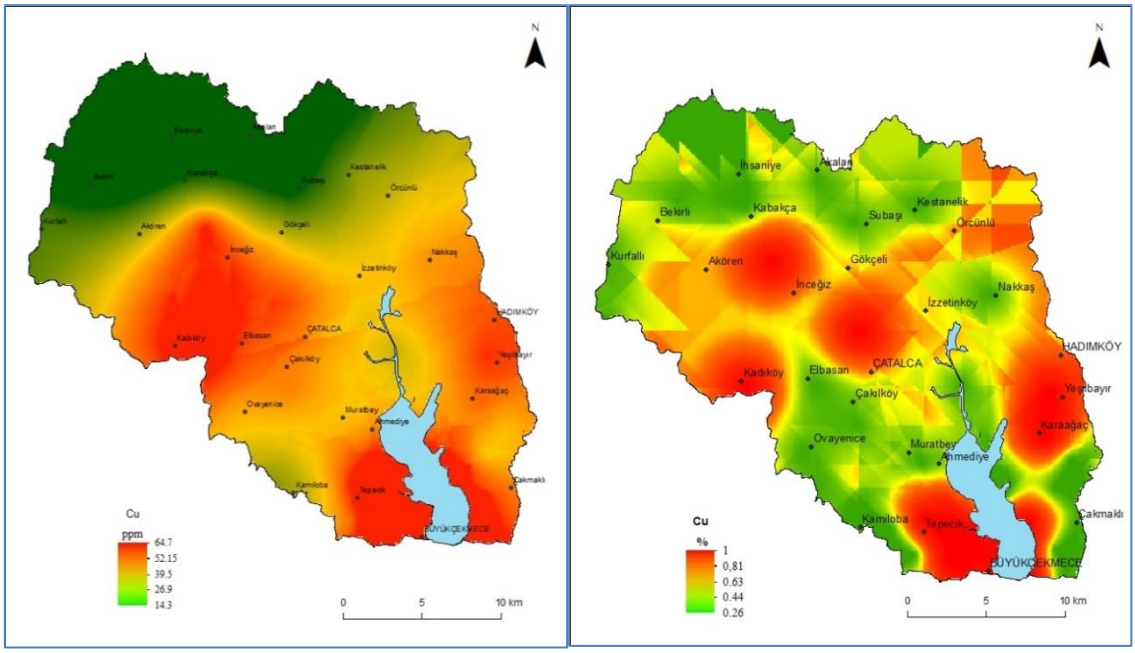

Figure 7 and 8: Copper (Cu) Concentration of the Surface Soils in the Büyükçekmece Lake Basin and Probability of Cu Values Exceeding 50 ppm

It is thought that various chemicals used in agricultural activities were the cause of high levels of copper (Cu) detected at some stations in the north of the study area and products industry is very close in the study area. Previous studies have shown that various chemicals used in agricultural activities and traffic intensity, vehicle emissions, industrial facilities are reason for the spatial variation of the copper metal concentration (Mentese, 2015). The areas, where the probability of copper (Cu) contamination exceeding 50 ppm to be over 81%, were around the Büyükçekmece Lake (81-100 %). These areas are the most risky regions of the study area in terms of copper contamination (Figure 7, 8 and 13).

The third element examined in the study area is zinc (Zn)**.** Zinc is used in metal coating, battery, medicine, paper and paint industries (Yalçın, 2014). The excessive intake in human body causes complaints such as delayed healing of the wounds, increased cholesterol, diarrhea, abdominal pain, loss of appetite, problems in the digestive system and decreased activity in the immune system (Deveci, 2012).

The possibility of zinc (Zn) contamination in Büyükçekmece Lake Basin exceeding the limit of 150 ppm established in the Turkey Soil Quality Control Regulation was also shown in Figures 9 and 10. Areas shown in red color very risky, those shown in orange color risky, those shown in yellow color medium risky and areas shown in green color constituted low risk regions when examining Figures 9 and 10.

Areas with a probability of exceeding the limit value of 77 % in terms of zinc (Zn) contamination are very risky areas in the Büyükçekmece Basin. Therefore, the close vicinities of the Büyükçekmece Lake are among very risky regions. Other areas are within the risky areas (%77-54) in terms of zinc contamination. The area is very risky and risky when the entire study area is taken into account in terms of zinc concentration (Figure 9 and 10). The medium risky (%54-31) and low risk (<31%) areas are located in the north of Ovayenice and Muratbey. The existence of high levels of concentration in terms of zinc (Zn) contamination is due to residential areas and industrial activities (Figures 5 and 6).

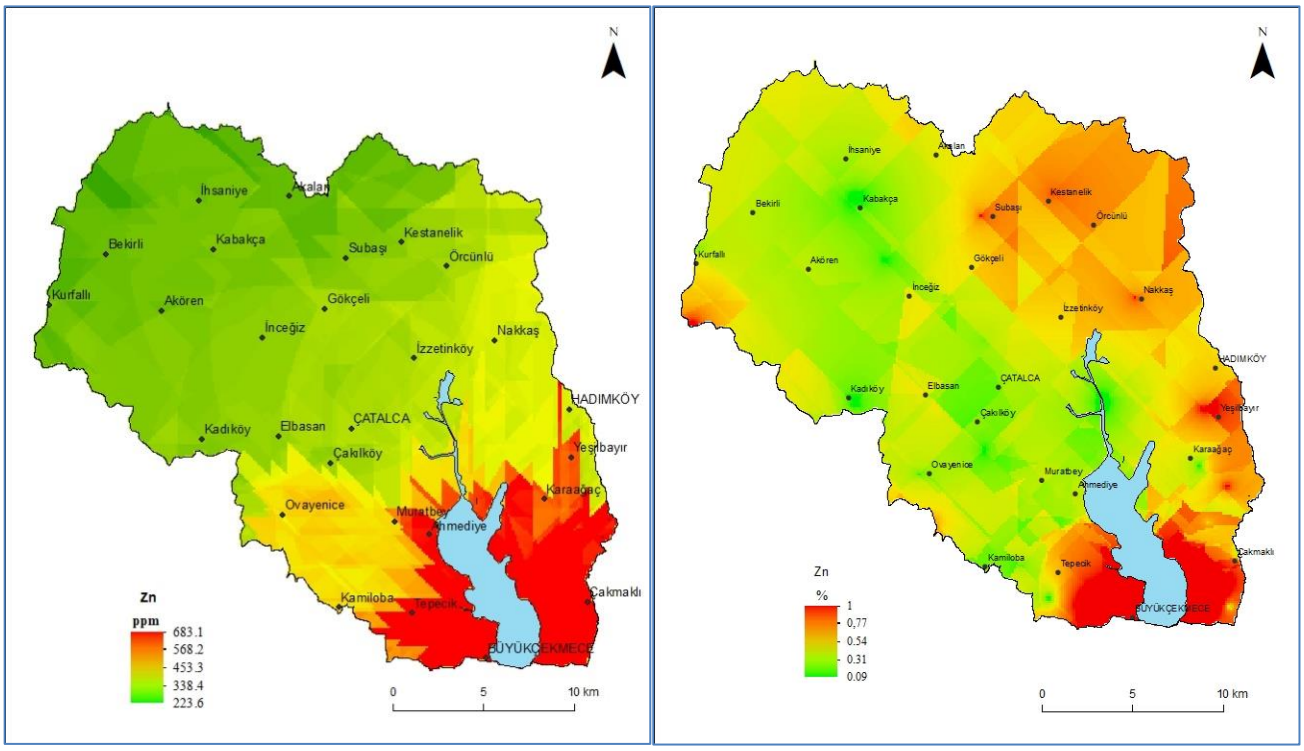

Figure 9 and 10: Zinc (Zn) Concentration of the Surface Soils in the Büyükçekmece Lake Basin and Probability of Zn Values Exceeding 150 ppm

The fourth element examined in the study area is cadmium (Cd). Cadmium metal is being used in steel coating, battery, ship, paint and electronics, detergent, and phosphate fertilizer industry. Their widespread use leads to cadmium contamination (Karadaş, 2008). Headache, sweating, fever, strain and pain in muscles, and fatigue are the symptoms of chronic cadmium poisoning. Prostate and lung cancer arise in chronic cadmium poisoning (Kahvecioğlu et al., 2001).

The possibility of cadmium (Cd) contamination in Büyükçekmece Lake Basin exceeding the limit of 1ppm established in the Turkey Soil Quality Control Regulation was also shown in Figures 11 and 12. Areas shown in red color very risky, those shown in orange color risky, those shown in yellow color medium risky and areas shown in green color constituted low risk regions when examining Figures 11 and 12. Areas with a probability of exceeding the limit value of

75 % in terms of cadmium contamination are very risky areas in the Büyükçekmece Lake Basin (Figure 11,12 and 13). Therefore, the close vicinities of the Lake Büyükçekmece and Çatalca, İnceğiz, Kadıköy are among very risky regions. Other areas are within the risky areas (%75-50) in terms of cadmium (Cd) contamination. The area is very risky and risky when the entire study area is taken into account in terms of cadmium concentration. The medium risky (%50-25) and low risk (<25%) areas are located in the north of Kadıköy, Elbasan, Subaşı, kurfalı and in the west of Tepecik, Elbasan, Bekirli. The existence of high levels of concentration in terms of cadmium (Cd) contamination is due to residential areas and industrial activities (Figures 5 and 6).

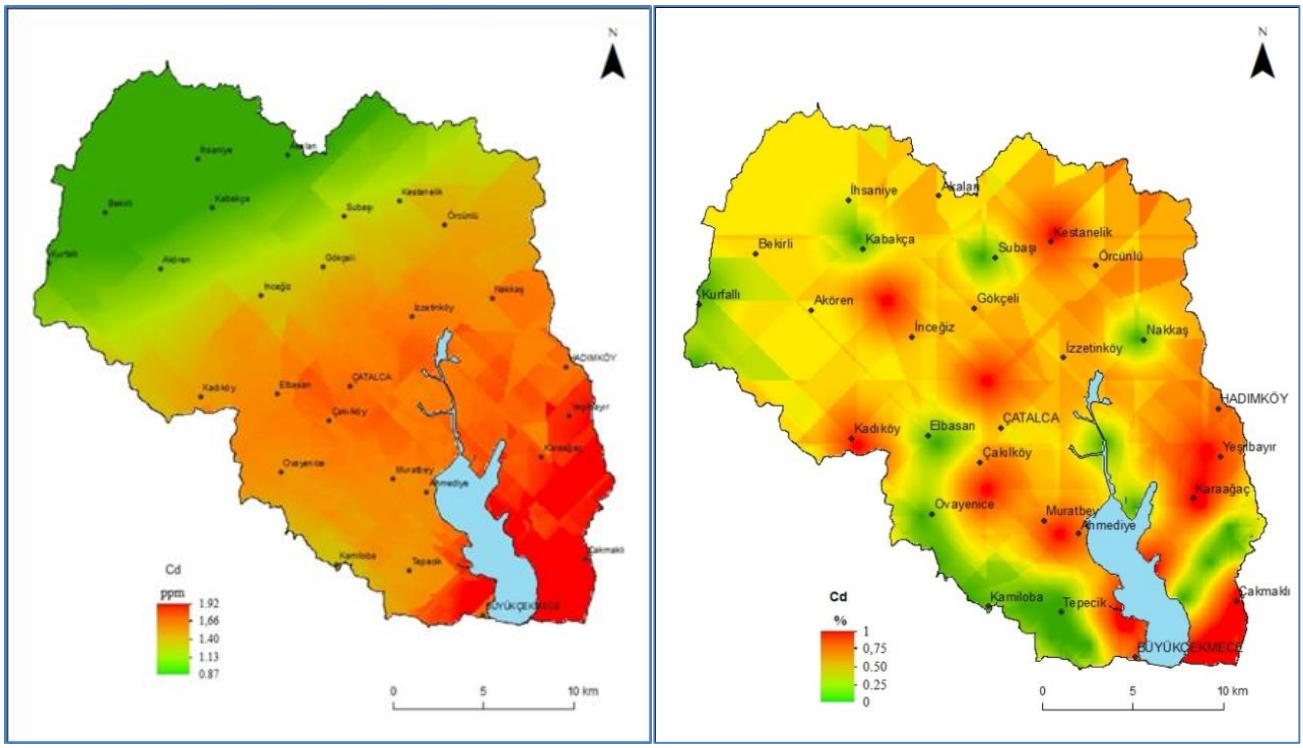

Figure 11 and 12: Cadmium (Cd) Concentration of the Surface Soils in the Büyükçekmece Lake Basin and Probability of Cd Values Exceeding 1 ppm

CONCLUSION

The spatial variation and sources of contamination of zinc (Zn), nickel (Ni), cadmium (Cd) and copper (Cu) heavy metals in the surface soils of Büyükçekmece Lake Basin were examined in this study. Zinc (Zn), nickel (Ni), cadmium (Cd) and copper (Cu) concentration levels were identified to be at high levels especially around the Büyükçekmece Lake as a result of the analyses conducted. There was a concentration level of about each one the limit values in the vicinity of the Lake where the highest values were measured for all of the heavy metals. The probability of exceeding the limit value for each one contaminants was over 50% in the entire study area. Therefore, the study area falls within very risky and risky regions (Figure 13).

In the Büyükçekmece Lake Basin, soil resources are contaminated as a result of residential and industrial wastes. High contamination levels, detected throughout the Basin, are due to industrial establishments, roads and residential areas. For this reason, the effect of pollutants is increasing in places close to cities but, decreases as its move away from cities. Heavy metals concentration levels were identified to be at high levels especially around the Büyükçekmece Lake as a result of the analyses conducted. The zinc (Zn), nickel (Ni), cadmium (Cd) and copper (Cu) concentration values, detected in the soil on Büyükçekmece Lake Basin, will increase day by day if the measures are not taken. Thus, zinc, nickel, cadmium and copper metals will pass on to living creatures and affect their health negatively. Therefore, it is necessary to reduce the pollution elements by continuous monitoring of the discharges arising from the industrial establishments and residential areas in Büyükçekmece Lake Basin and its surroundings.

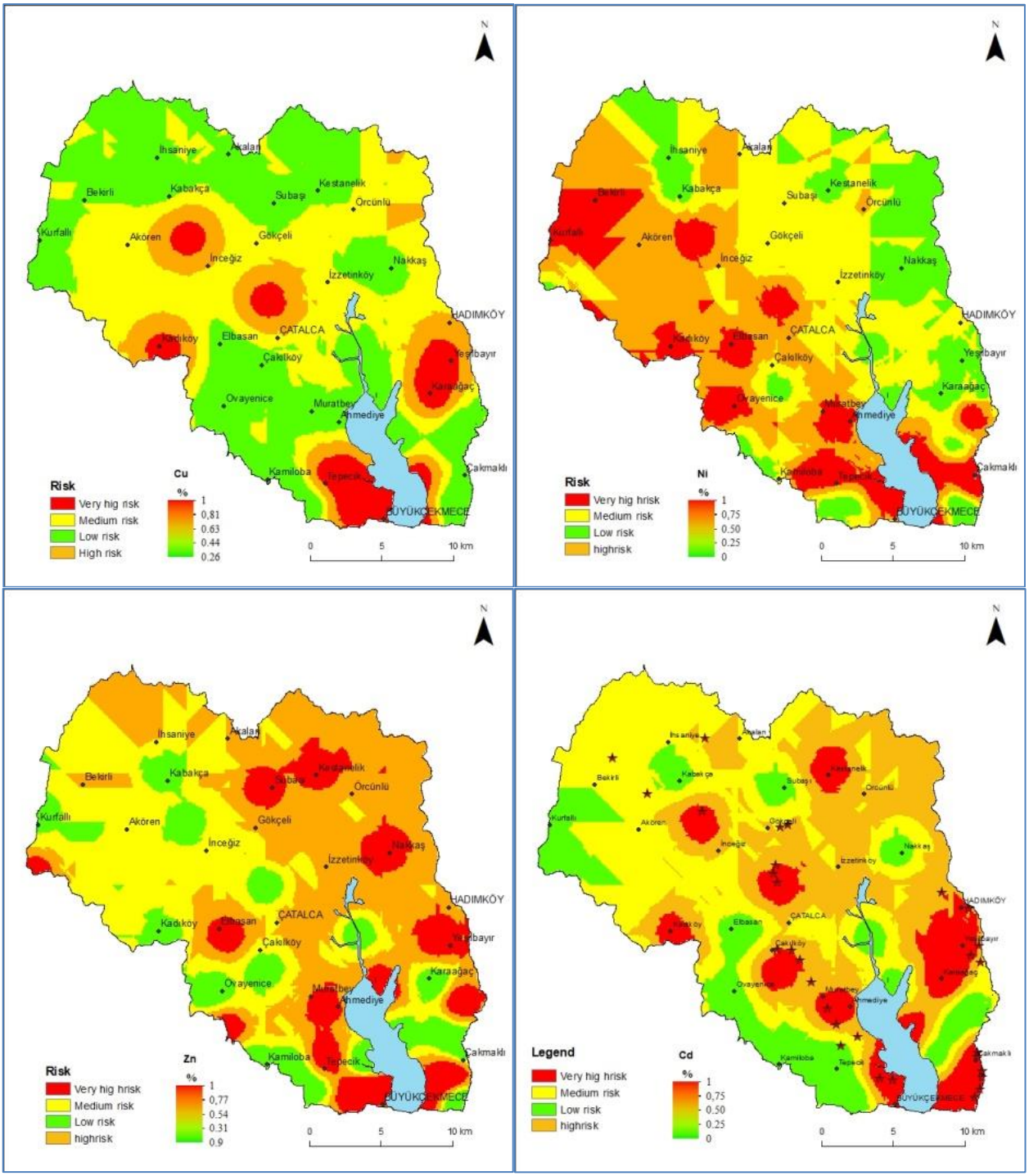

Figure 13: Copper (Cu), Nickel (Ni), Zinc (Zn), Cadmium (Cd) and Risk Map in the Büyükçekmece Lake Basin

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