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Evaluation of As, Cd, Ni and Se Content of Some Mineral Concrete Agents

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Abstract: In this study, the variation of arsenic (As), cadmium **(**Cd), nickel **(**Ni) and selenium **(**Se) concentrations in some materials used as concrete admixtures were evaluated. These heavy metals are extremely hazardous elements for both human and other living organisms and the environment. Due to these hazards, they are on the priority pollutant list of both ATSDR and EPA. Study results show that heavy metal concentrations in some additives are at very high levels. As a result of the study, the highest As concentrations were obtained in copper slag, vermiculite and cem III cement, the highest Cd concentrations in crushed stone and copper slag, the highest Ni concentrations in copper slag, wood ash and brick powder, and the highest Se concentrations in blast furnace slag and cem III cement. This may pose a great risk to the health of people working in the industry and the environment.

Keywords: Concrete, additive, heavy metals

Öz: Bu çalışmada beton katkı maddesi olarak kullanılan bazı malzemelerdeki arsenik (As), kadmiyum (Cd), nikel (Ni) ve selenyum (Se) konsantrasyonlarının değişimi değerlendirilmiştir. Bu ağır metaller hem insan hem de diğer canlı organizmalar ve çevre için son derece tehlikeli elementlerdir. Bu tehlikeler nedeniyle hem ATSDR hem de EPA'nın öncelikli kirletici listesinde yer almaktadırlar. Çalışma sonuçları bazı katkı maddelerindeki ağır metal konsantrasyonlarının çok yüksek seviyelerde olduğunu göstermektedir. Çalışma sonucunda en yüksek As konsantrasyonları bakır cürufu, vermikülit ve cem III çimentosunda, en yüksek Cd konsantrasyonları kırmataş ve bakır cürufunda, en yüksek Ni konsantrasyonları bakır cürufu, odun külü ve tuğla tozunda, en yüksek Ni konsantrasyonları ise bakır cürufu, odun külü ve tuğla tozunda elde edildi. yüksek fırın cürufu ve cem III çimentosunda en yüksek Se konsantrasyonları. Bu durum endüstride çalışan insanların ve çevrenin sağlığı açısından büyük bir risk oluşturabilir.

Anahtar Kelimeler: Beton, katkı maddesi, ağır metaller

1. Introduction

The world population has now exceeded 8 billion and the proportion of the population living in urban areas has exceeded 50%. By 2030, it is estimated that the world population will exceed 8.5 billion and the proportion of the population living in urban areas may reach 90% [1-3]. Studies reveal that the most important global problems today are global climate change [4], urbanization [5] and environmental pollution [6].

Population growth and the concentration of population in urban areas cause a significant increase in the number of people living per unit area. Therefore, the construction of high-rise buildings in urban areas, which allow more people to live in the unit area, becomes compulsory [7, 8]. The basic building block of most of these buildings is concrete [9]. Today, concrete is the most consumed building material after water [10].

Concrete is also one of the most important expense items of construction costs. In order to reduce concrete costs, the use of various substances as concrete admixtures has become quite widespread [11, 12]. In recent years, many studies have been conducted on the use of various wastes generated as a result of production activities in other sectors as concrete admixtures. The use of these materials as concrete admixtures not only reduces concrete costs but also contributes significantly to the reduction of environmental pollution [13, 14].

Therefore, the use of various waste materials as concrete admixtures is one of the most important research topics. However, there is a significant lack of information on the chemical composition of these admixtures [15]. The lack of sufficient data on the chemical structure of concrete admixtures leads to a lack of information on the environmental effects of construction activities as well as the health of people working in the sector. In this study, it was aimed to determine the As, Cd, Ni and Se contents of some admixtures used as concrete admixtures, which are extremely harmful for human and environmental health. Since these metals are extremely harmful to human and environmental health, they are included in the priority pollutant list of both US Environmental Protection Agency (EPA) and Agency for Toxic Substances and Disease Registry (ATSDR) [16].

Within the scope of the study, the concentrations of As, Cd, Ni and Se in some admixtures used as concrete admixtures were evaluated. The elements subject to the study are among the elements that are extremely dangerous for human and environmental health. In recent years, international health organizations have been classifying elements according to their hazards. In the studies conducted, ATSDR (Agency for Toxic Substances and Disease Registry) included 23 elements in the priority pollutant list due to their potential harm to humans and the environment. These elements are Ag, Al, As, Ba, Be, Cd, Co, Cr, Cu, Pb, Mn, Hg, Ni, Pd, Pu, Sb, Se, Sr, Tl, Th, U, V and Zn (28). Another important organization, EPA (U.S. Environmental Protection Agency) has defined Sb, As, Be, Cd, Cr, Cu, Pb, Hg, Ni, Se, Ag, Ti and Zn as Priority Pollutant Metals. The elements subject to the study are on both ATSDR and EPA's list of priority pollutants.

2. Material and Method

Within the scope of the study, it is aimed to determine the As, Cd, Ni and Se contents of some concrete mineral admixtures. For this purpose, samples were taken from these materials. Some of these materials are waste materials that are environmental pollution factors. The admixtures used within the scope of the study are as follows:

Table 1. Some of waste materials

No	Code	Material Names
M1	GDA	Recycling aggregate
M2	YFC	Blast furnace slag
M3	UCK	Fly ash
M4	KRC	Lime
M5	ODK	Wood ash
M6	ALC	Plaster
M7	KMT	Crushed Stone
M8	PMZ	Pumice
M9	TBK	Bottom ash
M10	SKU	Silica sand
M11	TGT	Brick powder
M12	SLD	Silica fume
M13	BKC	Copper slag
M14	CII	Cem II Cement
M15	VKL	Vermiculite
M16	CIV	Cem IV Cement
M17	DYT	Diatomite
M18	CIII	Cem III Cement
M19	CI	Cem I Cement
M20	LST	Tire powder
M21	MMT	Marble powder
M22	ZEO	Zeolite
M23	PRL	Perlite
M24	KRP	Red pumice

The materials obtained within the scope of the study were ground, sieved, then kept under laboratory conditions for two weeks until room dry and then placed in glass petri dishes and dried in an oven at 45 °C for two weeks. From the dried samples, 0.5 g of the sample was weighed and placed in tubes designed for microwave and 10 ml of 65% HNO_3 and 2 ml of 30% H_2O_2 were added. The prepared samples were incinerated in a specially designed microwave device at 280 PSI pressure and 180 ºC for 20 minutes. After the tubes removed from the microwave were cooled, deionized water was added and filled to 50 ml. The samples were filtered through filter paper and read at appropriate wavelengths in ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometry). This method is one of the most frequently used methods for elemental determination in recent years and is also used to determine the elemental content of concrete admixtures [15]. In the study, all measurements were performed in triplicate and the results of the study were evaluated at ppb level for higher sensitivity. The data obtained were evaluated by applying analysis of variance and Duncan test using SPSS 22.0 package program.

3. Findings

The variation of As, Cd, Ni and Se concentrations in the materials subject to the study on the basis of materials and statistical analysis results are given in Table 2.

Table 2. Statistical analysis of As, Cd, Ni and Se concentrations

Materials	As (ppb)	Cd (ppb)	Ni (ppb)	Se (ppb)
GDA	55.585,3 de	906,2 m	9.616,9 g	8.810,2 g
YFC	1.973.397,5 n	268,0 a	3.304 c	44.326,3 s
UCK	197.070 j	478,7 de	13.272,8 h	9.441,1 h
KRC	7.541,2 a	457,7 cd	24.380,7 k	7.672,7 f
ODK	506.635 k	791,8 k	99.194,4 t	12.482,7 i
ALC	24.502,2 b	469,8 cde	3.960,1 cd	5.927,3 d
KMT	5.897,3 a	1.461,8 n	3.863,8 cd	6.684,8 e
PMZ	58.250,6 e	472,1 de	5.795,6 e	8.765,3 g
TBK	90.198,3 g	488,5 de	14.820,3 i	9.339,1 h
SKU	3.822,3 a	523,2 f	8.374,8 f	4.138,8 c
TGT	49.453,3 cd	759,1 j	71.638,3 s	27.996,3 n
SLD	9.510,3 a	563,6 g	3.665,8 c	2.546,8 b
BKC	1.385.854,2 m	1.441,6 n	366.595,0 u	36.968,8 r
CII	73.646,1 f	823,8 l	37.284,4 n	19.149,2 k
VKL	636.816,7 l	563,3 g	17.241,1 j	32.074,3 o
CIV	148.853,2 i	625,8 h	25.231,1 l	19.462,5 k
DYT	42.243,7 c	501,9 ef	53.682,3 r	16.887,9 j
CIII	2.102.506,7 o	460,8 cd	31.677 m	45.300,9 t
CI	150.669 i	748,9 j	39.361,6 o	26.070,8 m
LST	8.490,4 a	755,1 j	4.473,8 d	2.831,5 b
MMT	5.226,9 a	735,3 j	2.644,7 b	5.904,3 d
ZEO	112.339,9 h	367,8 b	4.531,9 d	22.887,7 l
PRL	6.944,8 a	437,7 c	1.603,8 a	1.929 a
KRP	154.639,3 i	677,5 i	4.0309 p	34.338,5 p
F value	6.458,779***	758,926***	103.658,039***	7517,605***

p<0,001=%99,9 p<0,01=%99 p<0,05=%95 p>0,05=ns

When the results of the table are analyzed, it is seen that the variation of As, Cd, Ni and Se on the basis of materials is statistically significant at 99.9% confidence level (p<0.001). As a result of Duncan test, it was determined that the materials formed 15 groups for As, 14 groups for Cd, 20 groups for Ni and 19 groups for Se. The graph showing the change in As concentration on the basis of materials is given in Figure 1

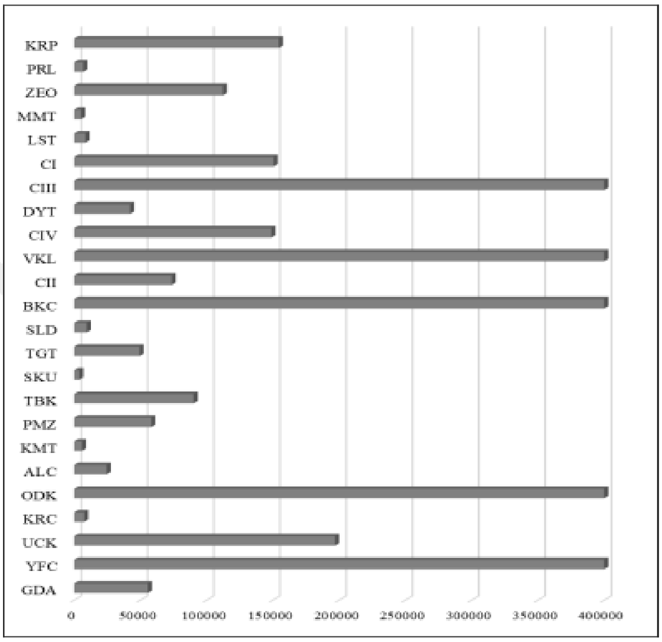

Figure 1. Variation of As (ppm) concentration by materials

Figure 1 shows that As concentration varies between 2,102,506.7 ppb and 3,822.3 ppb. The lowest values were obtained in SKU (3,822.3), MMT (5,226.9) and KMT (5,897.3), while the highest values were obtained in YFC (1,973,397.5), ODK (506,635), BKC (1,385,854.2), VKL (636,816.7) and CIII (2,102,506.7). When the values are analyzed, it is determined that there is approximately 550-fold difference between the lowest value and the highest value. Looking at the graph, the values were generally below 150,000 ppb. Only YFC (1,973,397.5), UCK (197,070), ODK (506,635), BKC (1,385,854.2), VKL (636,816.7), CIII (2,102,506.7) and KRP (154,639.3) exceeded this limit. The graph showing the variation of Cd concentration by materials is given in Figure 2.

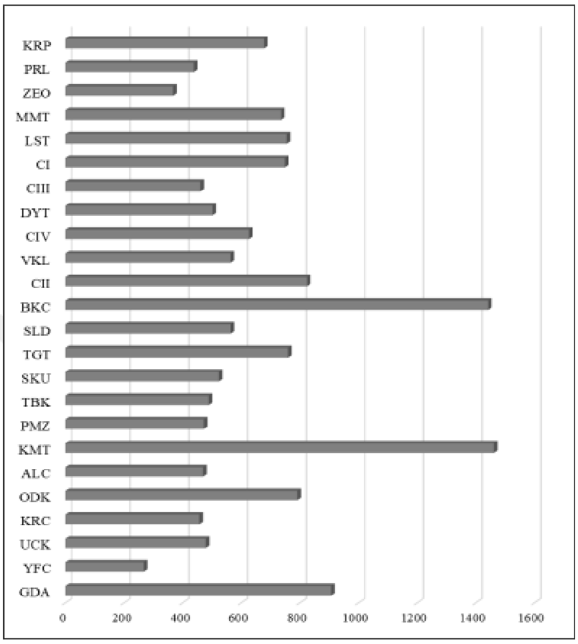

Figure 2. Variation of Cd (ppm) concentration by materials

Figure 2 shows that Cd concentration varied between 1,461.8 ppb and 268 ppb. The lowest values are observed in YFC (268.0) and ZEO (367.8), while the highest values are observed in KMT (1,461.8) and BKC (1441.6). When the values are analyzed, it is determined that 5.5 times the smallest value is equal to the largest value. When the graph is considered, it is seen that the values are generally below 600 ppb. Only GDA (906.2), ODK (791.8), KMT (1,461.8), TGT (759.1), BKC (1,441.6), CII (1,441.6), CIV (625.8), CI (748.9), LST (755.1), MMT (735.3) and KRP (677.5) were found to exceed this limit. The graph showing the variation of Ni concentration by materials is given in Figure 3.

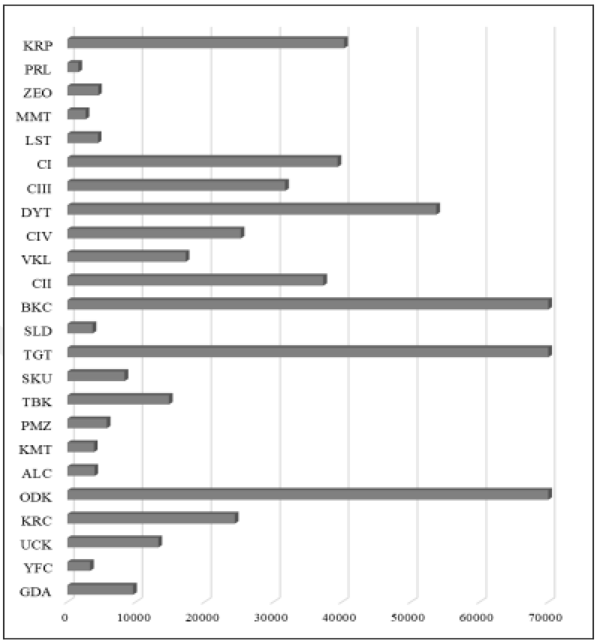

Figure 3. Variation of Ni (ppm) concentration by materials

Figure 3 shows that Ni concentration ranged between 366.595 ppb and 1.603,8 ppb. The lowest values were obtained in PRL (1.603,8), YFC (3.304), ALC (3.960,1), KMT (3.863,8) and MMT (2.644,7) while the highest values were obtained in BKC (366.595,0), ODK (99.194,4) and TGT (71.638,3). When the values were analyzed, it was determined that there was a difference of approximately 229 ppb between the lowest value and the highest value. In general, the values remained below 40,000 ppb. Only ODK (99,194.4), TGT (71,638.3), BKC (366,595.0) and DYT (53,682.3) exceeded this limit. The graph showing the variation of Se concentration by materials is given in Figure 4.

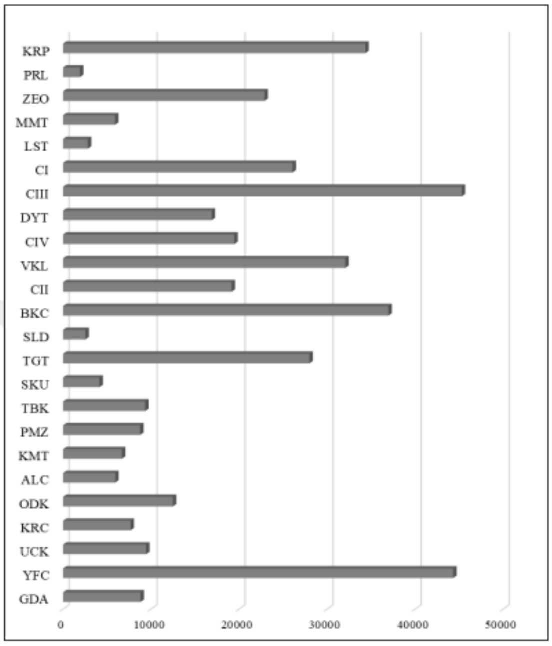

Figure 4. Variation of Se (ppm) concentration by materials

Figure 4 shows that Se concentration varied between 45,300.9 ppb and 1,929 ppb. The lowest values were obtained in PRL (1.929), LST (2.831,5) and SLD (2.546,8) while the highest values were obtained in YFC (44.326,3), TGT (27.996,3), BKC (36.968,8), VKL (32.074,3), CIII (45.300,9) and KRP (34.338,5). When the values were analyzed, it was determined that the lowest value was equal to the highest value of 23.5 ppb solid. Looking at the graph, the values were generally below 20,000 ppb. Only YFC (44,326.3), TGT (27,996.3), BKC (36,968.8), VKL (32,074.3), CIII (45,300.9), CI (26,070.8), ZEO (22,887.7) and KRP (34,338.5) exceeded this limit.

4. Results and Discussion

Heavy metals are elements whose concentrations in nature are constantly increasing, most of which are released into nature from anthropogenic sources such as mining, industry and traffic. They do not degrade or disappear easily in nature. Most of them are toxic, carcinogenic and fatal for living organisms even at low concentrations [17, 18]. Heavy metals, which are also the subject of this study, are elements that can pose a threat to human and environmental health even at low concentrations.

The values obtained as a result of the study may even exceed the values obtained in traffic and industrial zones, which are shown as the main sources of heavy metal pollution. For example, in a study conducted on road dust, it was determined that Cd concentration ranged between approximately 2.500 ppb and 4.500 ppb and Ni concentration ranged between 11.400 ppb and 22.400 ppb [19]. In this study, the concentrations obtained in some admixtures were much higher. According to these results, inhalation during the use of concrete admixtures may cause significant health risks. Because studies have shown that heavy metals are much more harmful if inhaled into the human body [3].

It is stated that construction activities, especially in urban centers, are one of the factors that most affect the amount of particulate matter in the air both during construction and demolition [15]. These particulate matter serve as a gathering center for heavy metals in urban areas. The chemical structure of particulate matter can also greatly affect heavy metal pollution in the air and subsequently in soil and water [20, 21]. Therefore, concrete admixtures can pose a major risk to the health of workers in construction activities. In addition, these particles may also adversely affect the health of people and living things living in urban areas.

Another striking result when the values obtained as a result of the study are examined is the differences between the lowest and highest values. For example, in As, one of the most harmful heavy metals for human health, there is approximately 550 times difference between the values obtained in the materials subject to the study. This result shows that the chemical content of waste materials used as concrete admixtures can be very variable. Similar results were obtained for heavy metals such as Pb, Cr, Zn and Ba [15].

Heavy metal pollution is one of the most important environmental threats today [22, 23]. Environmental pollution is considered to be the most important problem on a global scale together with problems such as global climate change [24, 25] and urbanization [26-28]. The most important components of environmental pollution are heavy metals (11). Therefore, studies on monitoring and reducing heavy metal pollution are very current [29-32]. The results of the study reveal that the additives subject to the study contain high levels of heavy metals. The use of these substances will also contribute to the reduction of heavy metal pollution.

5. Conclusions

A total of 4 heavy metals were evaluated within the scope of the study. However, heavy metals such as Sb, Be, Ag and Cr, which are not subject to the study and are also included in the priority pollutant lists of organizations such as ATSDR and EPA, are also elements that pose a great risk to human and environmental health. Therefore, it is recommended that studies on the subject should be continued by diversifying and increasing, and other heavy metals should be subject to similar studies.

The materials subject to the study are waste materials and the use of these materials in recycling contributes significantly to reducing their environmental impact. Therefore, besides the use of these materials as concrete admixtures, their use in other areas should be investigated.

The heavy metals evaluated in this study are among the most dangerous heavy metals for human and environmental health. During the use of these substances as concrete additives, workers may be at great risk. Therefore, workers should be warned, necessary precautions should be taken and inspections should be carried out, especially when using heavy metals with high concentrations. Some of these materials are also used as raw materials in other sectors. Employees working in these sectors should also be warned and necessary precautions should be taken.

Conflict of Interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Ethics Committee Approval

Ethics committee approval is not required.

Author Contribution

Conceptization: ISIE, HŞ; methodology and laboratory analyzes: ISIE, HŞ; writing draft: ISIE, HŞ; proof reading and editing: Other: All authors have read and agreed to the published version of manuscript.

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