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Assessing the Co, Bi, and Mg Contents of Some Mineral Concrete Additives in terms of Environmental Effects

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Abstract: Concrete additives started to be used commonly in order to reduce the cost of concrete, which is widely used in construction industry, and to recycle some wastes that are harmful to the environment. However, these additives might include heavy metals that are very harmful to human and environmental health and the number of studies on this subject is very limited. Besides the health of individuals working in this industry, it also creates a lack of knowledge about the environmental effects of construction activities. In the present study, among the heavy metals that can be very harmful to human and environmental health, Co, Bi, and Mg concentrations in some concrete additives were examined. The results showed that heavy metal concentrations in various concrete additives including copper slag, vermiculite, brick dust, Cem III cement, and blast furnace slag were very high. It might pose a risk to the health of individuals working in this industry, as well as the environmental health.

Keywords: Concrete, Additive, Cobalt, Bismuth, Magnesium

Öz: İnşaat sektöründe yaygın olarak kullanılan betonun maliyetini düşürmek ve çevreye zararlı bazı atıkların geri dönüştürülmesi amacıyla beton katkı maddeleri yaygın olarak kullanılmaya başlanmıştır. Ancak bu katkı maddeleri insan ve çevre sağlığına çok zararlı ağır metaller içerebilir ve bu konudaki çalışma sayısı oldukça sınırlı olduğu bilinmektedir. Bu sektörde çalışan bireylerin sağlığının yanı sıra inşaat faaliyetlerinin çevresel etkileri hakkında bilgi eksikliği de yaratmaktadır. Bu çalışmada insan ve çevre sağlığına çok zararlı olabilecek ağır metallerden bazı beton katkı maddelerindeki Co, Bi ve Mg konsantrasyonları incelenmiştir. Sonuçlar, bakır cürufu, vermikülit, tuğla tozu, Cem III çimentosu ve yüksek fırın cürufu gibi çeşitli beton katkı maddelerindeki ağır metal konsantrasyonlarının çok yüksek olduğunu göstermiştir. Bu sektörde çalışan bireylerin sağlığı ve çevre sağlığı açısından risk oluşturabilir.

Anahtar Kelimeler: Beton, Katkı, Kobalt, Bizmut, Magnezyum

1. Introduction

Social life and demographic structure on the earth have significantly changed in the last century due to the direct and indirect effects of the industrial activities. The most obvious effects of this change include global climate change, urbanization, and environmental health, which are among the most important problems worldwide. Increasing population density in urban areas necessitated the construction of multilayered buildings hosting more individuals in the unit area. Besides the construction of new buildings, also the replacement of old buildings with new ones requires the use of concrete at high amounts [1-8]

Concrete is the second-most used construction material (following the water) and it is the main constituent of buildings [9-11]. Thus, the content of concrete is very important from the aspect of environmental effects because it was reported that construction activities are among the factors affecting the amount of particles in the air during both construction and destruction phases [12]. Particle materials are among the ones determining the air quality [13] and the chemical structure of the particles in concrete composition is important for the environmental pollution [14-16]. Hence, the chemicals in the concrete additives might pose risk to workers working during the construction of building, individuals living in those buildings, and also the entire environment during the destruction [12]. For this reason, it is very important to determine the harmful element content of the additives constituting the concrete.

The scope of this study, Co, Bi, and Mg concentrations of some concrete additives were compared. Among the elements examined here, cobalt (Co) is an element that has toxic effects and, when inhaled, it causes alveoli, bronchus tumors, acute inflammation, alveoli epithelial hyperplasia, bronchial necrosis, and lung cancer [17]. Inhalation of bismuth (Bi) results in airway irritation and gingivitis, whereas oral intake of this element causes nausea, loss of appetite and weight, weariness, albuminuria, diarrhea, skin reactions, headache, fever, sleeplessness, and depression due to sulfur

accumulation [18]. The least harmful among the elements examined here is Magnesium (Mg) and Mg is the central atom of chlorophyll and plays a vital role in photosynthesis. The surplus of magnesium prevents the intake of potassium and negatively affects the root development of trees [19]. However, Mg is one of the heavy metals and previous studies showed that even the heavy metals, which are necessary as nutrient elements for organisms, are harmful when at high concentrations [20-23]. Moreover, it is known that inhaled heavy metals are very harmful to the human organism [24].

Even though these elements are very important for human and environmental health, the number of studies examining the chemical contents of concrete additives is not enough. In the present study, it was aimed to compare the Co, Bi, and Mg contents, which can be very harmful to human and environmental health, in some concrete additives.

2. Material and Method

Within the scope of this study, it was aimed to compare Co, Bi, and Mg contents of some mineral concrete additives. For this purpose, the mineral additives used as concrete additives most widely, especially the cement that is the main ingredient of concrete, were determined and samples were taken from recycling aggregate, blast furnace slag, fly ash, lime, wood ash, plaster, crushed stone, pumice, bottom ash, silica sand, brick dust, silica fume, copper slag, Cem I, Cem II, Cem II and Cem IV Cement, vermiculite, diatomite, rubber powder, marble powder, zeolite, perlite, and red pumice.

The materials obtained within the scope of this study were prepared for preliminary analyses. At this step, these materials were ground and sieved. Then, they were kept under laboratory conditions for 2 weeks until they became air-dried. Then, taking them into petri dishes, they were dried in drying oven at 45 °C for two weeks. Taking 0.5g from dried samples, they were taken into tubes designed specifically for microwave oven and added with 10 ml 65% HNO_3 and 2 ml 30% H_2O_2. These samples were combusted in a specifically designed microwave device under 280 PSI pressure at 180 ºC for 20 minutes. After cooling, the tubes taken out of the microwave were added with deionized water to fill to 50 ml. The samples were filtered using filter paper and then scanned using an ICP-OES (Inductive Coupled Plasma-Optic Emission Spectrometer) device at an appropriate wavelength. This method is among the ones used in elemental determination the most in recent years [25-31] and it is also used for analyzing the concrete additives [12].

In this study, all the measurements were repeated three times and the data obtained were analyzed using Variance Analysis and Duncan's test in SPSS package program. The results obtained from Variance Analysis and Duncan's test were simplified, tabularized, and then interpreted.

3. Result and Discussion

The mean values for Co, Bi, and Mg elements examined here and the statistical analysis results are presented in Table 1.

Table 1. Elemental contents of solid materials

Materials	Co (ppb)	Bi (ppb)	Mg (ppm)
Recycling aggregate	2294.8 d	1502.3 ab	3344.3 i
Blast Furnace Slag	7461.8 l	9382.7 g	15347.1 v
Fly ash	5037.8 i	UnLim	2113.6 f
Lime	856.4 a	2703.1 cd	5821.7 k
Wood ash	8165.4 m	3375.9 d	10286.8 p
Gypsum	707.2 a	1759.9 abc	4530.8 j
Crushed Stone	806.6 a	2553.3 bcd	1332.3 e
Pumice	4017.4 g	684.7 a	762.0 c
Bottom ash	4351.3 h	1103.3 a	2091.4 f
Silica sand	1594.6 c	1124.9 a	420.6 b
Brick powder	23830.8 r	5679.2 e	10630.6 r
Silica fume	1126.8 b	UnLim	1067.8 d
Copper slag	82648.0 t	158643.2 i	6434.2 m
Cem II Cement	7028 k	5554.7 e	8481.2 o
Vermiculite	25195.3 s	4574.6 e	15246.2 u
Cem IV Cement	6208.3 j	4739.5 e	8166.3 n
Diatomite	2982.7 f	1018.8 a	6083.1 l
Cem III Cement	10129 n	11503.3 h	15356.0 v
Cem I Cement	7333.3 l	7935.3 f	12962.6 s
Tire dust	11248.8 o	UnLim	14.7 a
Marble powder	2748.3 e	1217.8 a	2341 g
Zeolite	1125.8 b	741 a	3198.3 h
Perlite	695 a	UnLim	UnLim
Red Pumice	18541.1 p	5218.6 e	15043.8 t
F Values	71815.061***	8378.837***	70321.087***

letter refers to the vertical direction, UnLim: Under detection limits, *** significant at 0.001 level.

As a result of the study, it was determined that Co concentration ranged between 695 ppb and 82648 ppb, that the lowest values were obtained in perlite (695.0 ppb), plaster (707.2 ppb), and crushed stone (806.6 ppb), whereas the highest values were obtained from copper slag (82648.0 ppb), vermiculite (25195.3 ppb), and brick powder (23830.8 ppb). It is interesting that there was a difference higher than three folds between copper slag yielding the highest value and vermiculite yielding the second-highest value.

Bi concentration remained below the detectable limits in fly ash, silica fume, rubber powder, and perlite. The lowest Bi concentrations were found in pumice (684.7 ppb), zeolite (741.0 ppb), and diatomite (1018.8 ppb), whereas the highest values were found in copper slag (158643.2 ppb), Cem III cement (11503.3 ppb), and blast furnace slag (9382.7 ppb). As with Co element, there was a very high level of difference between the highest value (copper slag) and the second-highest value (Cem III cement) and the difference was higher than thirteen folds.

Mg, the other element examined here, remained below the detectable limits in perlite and ranged between 14.7 ppm and 15356.0 ppm in other samples. The lowest Mg concentrations were obtained from rubber powder (14.7 ppm), silica sand (420.6 ppm), and pumice (762.0 ppm), whereas the highest concentrations were obtained from Cem III cement (15356.0 ppm), blast furnace slag (15347.1 ppm), and vermiculite (15246.2 ppm).

4. Discussion and Conclusion

As a result of the study, it was determined that the elements examined here were at very high concentrations in some concrete additives. These elements are classified as heavy elements and, from the aspect of health, many of heavy elements are toxic, harmful, and carcinogenic even at low concentrations [32]. Co, one of these elements, is in the preliminary pollutant list of ATSDR (Agency for Toxic Substances and Disease Registry) [33] and is harmful to organisms even when at low concentrations [34]. Thus, many studies were carried out in order to determine the concentration of Co in various environments [35-38]. However, Bi and Mg, the other elements examined in the present study, are among the ignored elements. On the other hand, it is emphasized that these elements might be harmful to health. For instance, Bi can cause diarrhea, headache, fever, and liver and kidney diseases [18], while it was stated that all heavy metals could cause severe disorders when inhaled [24].

Moreover, previous studies showed that even the heavy metals that are necessary as nutrient element for organic development might be harmful to health when at high concentrations [35-38]. For this reason, many studies have examined the concentrations of heavy metals in soil [39, 40], water [41-43], and air [44-49]. In recent years, the studies carried out on heavy metals were diversified more and many studies were carried out on heavy metal pollution caused by heavy metal sources such as traffic [50-53], industry [54], urban areas [55], and mining fields [56].

Remaining undegraded in nature for a long time since it has a long half-life, heavy metals that accumulate in bodies of organisms and can be toxic or carcinogenic even when at low concentrations are considered as one of the most dangerous environmental pollution factors [57-60]. For this reason, use of waste materials (especially heavy metals), many of which are important environmental pollutants, as a concrete additive is very important since it decreases the cost of concrete and it contributes to the reduction of environmental pollution by eliminating the environmental pollutants through recycling [61-64]. For this reason, many studies examining the use of various waste materials as concrete additives were carried out in recent years [65-67]. However, almost all those studies investigated the effects of those additives on concrete characteristics [68-71]. Yet, the number of studies on the chemical compositions of those additives is very limited.

5. Suggestions

As a result of this study, it was determined that the concentrations of Co, Bi, and Mg were very high in some concrete additives. Inhalation of additives, which were examined here, by workers while they are used as concrete additives might cause severe health risks. For this reason, attention should be paid to the use of copper slag, vermiculite, brick powder, Cem III cement, and blast furnace slag, in which the heavy metal pollutions were found to be high. Workers should be warned about the risks of these materials and necessary measures should be taken.

Among the additives examined here, the ones such as blast furnace slag and copper slag are the wastes of industrial facilities. The materials such as vermiculite are used in agriculture, and brick is used in various fields. Thus, the individuals working in these industries are exposed to the powders of these materials. The individuals working in other industries, where these materials are used, should be warned and it should be ensured that necessary measures would be taken.

Competing Interest / Conflict of Interest

The authors declare that they have no competing interests.

Author Contribution

We declare that all Authors equally contribute.

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