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Heavy Metal Contamination in the Soil and Taal Lake Post-Taal Volcano Eruption

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Abstract

Volcanic eruption can be a source of heavy metal contamination in the environment and such contamination may cause certain risks to the environment and to those who are exposed to the volcanic contents. This study aimed to assess the agricultural soil for heavy metal contamination after the 2020 Taal volcano eruption. The agricultural soil samples were collected from Cuenca and Talisay, Batangas and Tagaytay City, Cavite and were submitted to a laboratory for arsenic, cadmium and mercury detection and quantification. The detected metal concentrations were compared to the standard values of the Department of Environmental and Natural Resources for arsenic and United States Environmental Protection Agency for cadmium and mercury for soil samples while for the water samples, the standard values of Department of Environment and Natural sources were used. The soil from Talisay, Batangas had two-fold arsenic increase while the samples from Tagaytay City, Cavite had one-fold elevation. Cadmium and mercury in the soil and water were within the acceptable level in the three municipalities. The arsenic contamination of the soil post-volcanic eruption was probably due to the direction of the wind during the eruption, the amount of ashfall and groundwater contamination. Heavy metal contamination can be detected years after the eruption.

Keywords: arsenic; environmental hazards; natural calamity

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1. Introduction

Anthropogenic activities are the usual sources of heavy metal contamination in the Philippines (Enguito, 2013; Galarpe et al., 2017) but may also originate from natural sources such as volcanic eruption (Angelovicova & Fazekasova, 2014; Havugimana et al., 2018). The tephra may either be emitted into the stratosphere and troposphere or the ashes may reach the land and bodies of water during volcanic eruption. The tephra distribution may vary depending on the wind direction and speed (Jenkins et al., 2015; Fiantis et al., 2019). The volcanic ashes are emitted in the atmosphere during a volcanic eruption and later deposits into the land. It was observed that rainy season is observed after the volcanic eruption and it washed some of the volcanic ash contents into the water. In addition, the bodies of water become polluted with heavy metals when the ashes fell into the water during volcanic eruption or these heavy metals runoff into the water (He et al., 2018).

The released heavy metals become mobile and eventually spread to other bodies of water or reach the land. The crops subsequently absorb these metals (Liu & Ma, 2019). Lead, arsenic, nickel are volcanic trace elements that are moderately to extremely poisonous to humans. Other heavy metals in the environment that poses risks are mercury, cadmium, chromium, zinc and copper (Fiantis et al., 2010; Bharvaga et al., 2017). Water pollution in bodies of water has the most concentration of cadmium, lead, arsenic and mercury (Tang et al., 2018). These metals are deleterious to living organisms when ingested at excessive amounts or when there is prolonged exposure (Ali et al., 2019). Most of

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the local studies about heavy metal contamination are associated to anthropogenic activities (Cortez & Ching, 2014).Due to limited studies that discusses about heavy metal contamination from a volcanic eruption, the study aimed to assess the agricultural soil in affected municipalities and also the Taal Lake for heavy metal contamination after the 2020 Taal volcano eruption.

2. Methodology

2.1. Research design

The study is in descriptive approach that determined the presence and the concentration of mercury, arsenic and cadmium in the agricultural soil and Taal Lake. The soil and water samples in Batangas and Cavite within the 14-km danger zone of Taal volcano except for Cuenca, Batangas, were processed for the detection of mercury, arsenic and cadmium.

2.2. Soil collection process and heavy metal processing

Soil samples were collected from a land that is devoid of Mangifera indica (mango) and Musa (banana). These plants may absorb heavy metals in its roots and may accumulate to its plant parts (Romero-Estevez et al., 2019; Asuquo & Barde, 2020) and may give a negative result. The municipality of Talisay, Batangas was divided into 7 parts while Tagaytay City, Cavite into 6 parts. The agricultural soil was collected from farm house in each of the assigned parts of the municipalities. One sample was collected from the Cuenca, Batangas. This municipality represented the municipalities that are less affected by 2020 Taal volcano eruption.

The area of soil collection was divided into four quadrants, where 250grams of soil per quadrant were collected from an approximate depth of 10cm. A total of 1,000 grams of soil was obtained, then mixed together. The samples were placed in properly labelled polyethylene bag containers. Three replicate soil samples with 1,000grams per soil sample were collected from each location. All three were brought to Jefcor laboratories, Inc. for the detection of mercury, arsenic and cadmium. The soil samples were stored at room temperature and were dried prior to its processing in a laboratory. The soil samples was processed and underwent cold vapor atomic absorption spectrometry for mercury detection and quantification while Manual hydride generation Atomic absorption spectrophotometry (AAS) and direct air-acetylene flame were used in the detection and measurement of arsenic and cadmium in the soil samples, respectively. The results were released two (2) weeks after submitting the soil samples.

2.3. Taal Lake water collection process and heavy metal processing

The surface water of Taal Lake was collected in the morning between 8 a.m. to 12 noon from three locations in every municipality, Agoncillo, Cuenca and Talisay. One time collection of the water samples was done. The surface water sample measuring 500ml of the surface water, was collected 500 meters away from the shoreline and was placed in a properly labelled sterile glass bottle. The water samples from the three locations per municipality represented the three replicates of water samples in the municipality. One water sample from the each chosen barangay was collected. The water sample was submitted to a laboratory for heavy metal processing. Mercury in the water was detected and quantified using cold vapor Atomic Absorption Spectrometry while arsenic and cadmium was identified using the Manual hydride generation Atomic absorption spectrophotometry (AAS) and direct air-acetylene flame, respectively.

3. Data Gathering and Analysis

The concentration of mercury, arsenic and cadmium in the soil was presented in mean of three readings while the detected concentration in the Taal lake water in each location and the mean values of the 3 locations were reported. The detected heavy metal concentration of the surface water of Taal Lake were compared to the standard values set in the Department of Environmental and Natural Resources (DENR) Administrative order no. 2016-08 (Department of Environment and Natural Resources, 2016). Meanwhile, the detected arsenic values in soil samples were compared to the reference values of (DENR) Administrative order no. 2019-17 (Department of Environment and Natural Resources,

2019) while the detected values of mercury and cadmium were compared to the reference values of United states Environmental protection (US EPA).

4. Results

The soil samples were collected from Tagaytay City, Cavite and 2 municipalities from Batangas, Talisay and Cuenca, respectively. Among the three heavy metals, arsenic is the metal which was detected to have a concentration above the acceptable level in the barangays of 3 municipalities (Table 1). The highest concentration of Arsenic in the soil samples was identified in Talisay, Batangas particularly in Barangay Tumaway (7.91 ppm) while the lowest concentration of Arsenic was detected in Barangay Don Juan, Cuenca, Batangas (1.92 ppm). Cadmium and mercury concentration in the soil samples from the different municipalities were within the acceptable level that was set by US EPA.

Table 1. Comparison of detected heavy metal concentration of the soil of different municipalities to reference values

Barangay per municipality	Arsenic		Cadmium		Mercury	
Talisay	Mean (ppm)	Reference value (ppm)	Mean (ppm)	Reference value (ppm)	Mean (ppm)	Reference value (ppm)
Balas	5.37	*2.0*	<0.03	*0.075*	<0.08	*1.8*
Buco	4.62	*(DENR)*	<0.03	*(USEPA)*	<0.08	*(US EPA)*
Poblacion 4	5.38		<0.03		<0.08	
Quiling	4.43		<0.03		<0.08	
Sampaloc	4.70		<0.03		<0.08	
Tranca	4.41		<0.03		<0.08	
Tumaway	7.91		<0.03		<0.08	
Mean	5.26		<0.03			
Tagaytay						
Guinhawa South	3.79	*2.0*	<0.03	*0.075*	<0.08	*1.8*
Iruhin East	3.66	*(DENR)*	<0.03	*(USEPA)*	<0.08	*(US EPA)*
Iruhin West	2.12		<0.03		<0.08	
Mag-asawang Ilat	4.47		<0.03		<0.08	
Maharlika East	4.88		<0.03		<0.08	
Tolentino East	4.78		<0.03		<0.08	
Mean	3.94		<0.03		<0.08	
Cuenca						
Don Juan	1.92	*2.0* *(DENR)*	<0.03	*0.075* *(USEPA)*	<0.08	*1.8* *(US EPA)*

The Taal lake water was assessed for the presence of heavy metals. The study showed that the concentration of the aforementioned heavy metals were within the acceptable level. The highest concentration of Arsenic in Taal Lake water was detected in Barangay Quiling, Talisay, Batangas (0.0097 mg/L) but this is still significantly lower than the standard concentration of 0.02 mg/L. Table 2 demonstrated the concentration of arsenic, cadmium and mercury in Taal Lake water in Tagaytay City, Cavite, Talisay and Cuenca, Batangas.

5. Discussion

5.1. Heavy metal concentration in the soil

The direction of the wind during volcanic eruption, earthquake and ground water contamination may have affected the distribution of arsenic in the land. The wind during the 2020 Taal volcano eruption blew towards the north side of the volcano, where Tagaytay and Talisay are specifically sited, and few of the other volcanic contents on the opposite direction on the succeeding days. Moreover, significant amount of ashfall was observed on the provinces that was located on the northeast side of Taal volcano (Martinez Villegas et al., 2022). Aside from the abovementioned factors, earthquakes occurred prior, during and even after the volcanic eruption. These earthquakes have shaken the ground including the materials in the soil such as glasses and other disposed materials. Broken glasswares can be a source of arsenic in the environment. When heat and other substances react with the glass, arsenic are released from it (Bohrer et al., 2006). These factors may explain the significantly higher arsenic amounts in the soil of Tagaytay and Talisay than in Cuenca, Batangas. These concepts may have contributed in the distribution of arsenic concentration in other municipalities. Another factor that may also explain the presence of arsenic in the soil is the ground water contamination. Higher arsenic concentration was detected from the wells and other water sources from the different municipalities surrounding Taal volcano in year 2020 than 2021 (Apostol et al., 2022). Their study explained that the movement of the groundwater had an access to the volcanic contents and also in the soil . Despite having lower arsenic level in the water from the well 1 year after the Taal volcano eruption, these water sources may still move across the soil and there is a possibility that it can still flow through the soil when it rains. This may have also contributed in the arsenic detection in the soil. Meanwhile, there are local studies (Nolos et al., 2022; Posadas et al., 2022) that assessed for heavy metal contamination in the soil and cadmium and mercury were detected, respectively. Their findings are similar with the result of this study.

Table 2. Comparison of detected heavy metals in Taal Lake water of Batangas' municipalities to DENR standard values

Baranggay per municipality	Arsenic		Cadmium		Mercury	
Talisay	Result (mg/L)	Standard limit (mg/L)	Result (mg/L)	Standard limit (mg/L)	Result (mg/L)	Standard limit (mg/L)
Brgy. Quiling	0.0097		<0.003		<0.0004	
Between Brgy. Poblacion and Brgy. Balas	0.0089		<0.003		<0.0004	
Brgy. Sampaloc	0.0071		<0.003		<0.0004	
Mean	0.0082	*0.010*	<0.003	*0.005*	<0.0004	*0.002*
Agoncillo						
Between Brgy. Bilibinwang and Subic Ilaya	0.0084		<0.003		<0.0004	
Brgy. Banyaga	0.0052		<0.003		<0.0004	
Between Brgy. Guitna, Brgy. Teodoro and Brgy. Pansipit	0.0061		<0.003		<0.0004	
Mean	0.0066	*0.010*	<0.003	*0.005*	<0.0004	*0.002*
Cuenca						
Brgy Don Juan-Near Brgy. Calumayin	0.0095		<0.003		<0.0004	
Brgy. Don Juan						
Brgy Don Juan-Near			<0.003			
San Felipe	0.0050				<0.0004	
Mean			<0.003			*0.002*
	0.0072	*0.010*			<0.0004	
			<0.003	*0.005*		
	0.0072				<0.0004	

Soil contamination can be due to is due to natural and anthropogenic sources and it can be in the form of fuel, pesticides and fertilizers. Chemicals can be a source of heavy metal contamination in the soil. Arsenic is a heavy metal content that is present in fertilizers and pesticides (Wuana & Okieimen, 2011). In relation to the study, fertilizer was applied according to the residents, in the soil of Barangay Tumaway, Talisay, Batangas weeks prior to soil collection and also in the soil of Barangay Balas, Talisay, Batangas one month prior to soil collection and this may have affected the arsenic concentration in the soil. Meanwhile, no fertilizers had been applied in the soil of Barangay Poblacion 4, Talisay, Batangas, the different barangay in Tagaytay City, Cavite and Cuenca, Batangas. Despite not applying fertilizers, the soil sample from Barangay Poblacion 4 was detected to have arsenic that is almost three-fold higher than the standard level and the arsenic concentration in the soil of other municipalities are at least one-fold greater than the standard level. Aside from the fertilizers, heavy metals can also come from the air particularly from fossil fuels. In the community, the smoke from the burning of fuels will become dust particles which may settle on the ground (Wuana & Okieimen, 2011). In relation to the study, most of the collection sites in Tagaytay City, Cavite and municipalities in Batangas were approximately at least 30 meters away from the roadside. Despite the fact that fertilizers may promote the growth of plants, it may still contribute in the accumulation of arsenic in the soil. Soil with deleterious arsenic concentration may also interfere with the physical structure of the plants such as having smaller plant size, abnormal root development, and it may even limit the photosynthetic activity of plants (Shrivastava et al., 2015). The high arsenic concentration may explain the drying of the plants and limited number of plants that grew in Barangay Poblacion 4 and the small size of papaya fruit in Barangay Balas.

High arsenic concentration in Barangay Balas and Poblacion 4 were also detected even if no fertilizers had been applied. Some industrial companies are using arsenic in making glass and it can be a source of arsenic when it reacts with heat and other substances in the environment (Bohrer et al., 2016). In relation to the study, few broken glass wastes in Barangay Balas and porcelain glasswares in Barangay Poblacion 4 were found and observed during soil collection. The heat from the sun and also the other minerals in the soil may have reacted to the glass and triggered its release into the soil. This may explain the alarming arsenic concentration in some of the barangays in Talisay, Batangas.

Fertilizers contributed in the placement of arsenic in the soil as observed in Baranggay Tumaway and Balas, Talisay, Batangas. Dust particles from the burning of fuel and presence of broken glasses may have also increased the metal concentration in the soil such as arsenic. Moreover, arsenic-contaminated wells and other water sources from the surrounding municipalities of Taal volcano are also sources of heavy metal contamination in the soil. Given this information, a combination of natural and anthropogenic sources explains the alarming arsenic concentration in the soil of Talisay, Batangas. However, the deleterious level of arsenic in the soil is not limited to chemicals and materials because a significantly high arsenic concentration was also detected from barangays without any exposure to fertilizers and those with limited exposure to vehicular smoke. Since there is no significant anthropogenic sources that may emit heavy metals in most of the collection sites in Tagaytay City, Cavite and municipalities in Batangas, the volcanic ash may have contributed in its detection in their soil samples and this is most probably due to the wind direction, amount of ashfall and groundwater contamination.

5.2. Heavy metal concentration in Taal Lake water

Taal Lake surrounds the volcano and its location has exposed it to the volcanic contents during the eruption. Despite that, heavy metal contamination in the Taal lake water was observed but within the standard limit. The acceptable concentration of heavy metals in the lake water is most probably due to the timing of water collection, minimal drying of Taal Lake water and absence of direct contact to the volcanic contents. The collection of Taal Lake water took place two years after the volcanic eruption. The volcanic ashes from the eruption may either have settled on the sediments or have reached the land and these may have affected the presence of heavy metals on the surface of Taal Lake. Aside from the timing of water collection, the residents observed that the amount of Taal Lake water was reduced after the eruption and also the nearby rivers were affected. There was a news report of its drying and it is probably due to the evaporation of the water sources and also the seeping of water in the fissures. The drying of the Taal Lake water may have contributed in the control of heavy metal in the water after the volcanic eruption.

Aside from this, the continuous exposure to volcanic contents may also be considered. Dangerous arsenic concentration was detected from the wells and other water sources from the surrounding municipalities of Taal volcano. The groundwater is reported to have the volcanic rocks and its contents (Apostol et al., 2022). In relation to this study, Taal Lake has no direct contact to the volcanic materials unlike the groundwater. Given this information, Taal Lake may have been exposed to volcanic materials during the eruption but it has no continuous access to the volcanic contents several months and years after the eruption. Thus, this lake will not reach an alarming heavy metal concentration when its contamination is mainly based on a natural source.

Arsenic, cadmium and mercury were detected from Taal Lake water that is surrounding the different municipalities in Batangas and Tagaytay City, Cavite but their concentration is within the standard level. Like in the soil, heavy metal contamination of the water can be due to natural or anthropogenic sources (Chung et al., 2014). The breakdown of the rocks and volcanic eruption are the common sources of heavy metals while the other sources can be due to wastes from industrial companies, leaching of these metals from the fertilized and non-fertilized soil into the water sources and also exposure to burning of fossil fuels. Hazardous concentration of metal is commonly from industrial and mining companies (Singh et al., 2022). In relation to the study, the actual collection sites of Taal Lake water are distant from the soil sample sites and also the land. Moreover, there are no established industrial and mining companies in these municipalities. Thus, there are no significant anthropogenic activities that can be a continuous source of heavy metals in the water and this may explain the acceptable heavy metal concentration in the Taal Lake water.

The detected heavy metal concentration in Taal Lake is most likely due to an exposure to volcanic ash during the eruption and is not affected by anthropogenic sources such as burning of fossil fuels, wastes from companies and also washing off of heavy metals from fertilized or chemically-treated soil. Since there are no anthropogenic sources of heavy metals in the water, the heavy metal concentration in Taal Lake water is maintained below the standard levels. Exposure to volcanic ash during the eruption is most probably the only natural source of heavy metals in the lake water. The absence of direct and continuous contact flow to volcanic rocks prevented these heavy metals from causing heavy metal contamination in Taal Lake water.

6. Conclusion

The soil from affected municipalities of 2020 Taal volcanic eruption especially Talisay, Batangas and Tagaytay City, Cavite are more contaminated with heavy metal than Taal Lake water 2 years after the eruption. The direction of the wind during volcanic eruption, earthquake and groundwater contamination are the different factors that may have contributed to its heavy metal contamination in the soil. Aside from that, broken glasses, application of fertilizers and exposure to burning fossil fuels may have add up to the soil contamination. Thus, a combination of natural and anthropogenic sources increases the heavy metal concentration in the soil and these was observed in the soil samples of Baranggay Tumaway, Balas and Poblacion 4. Meanwhile, there was no heavy metal contamination in Taal Lake and this is most likely because the water was collected 2 years after the eruption and there is no direct contact to volcanic contents and groundwater. Since the eruption occurred 2 years ago, the volcanic materials may have already settled on the bottom of the lake. No external factors have further contributed in Taal Lake water contamination. Hence, heavy metal concentration in Taal Lake water is maintained within the standard concentration.

7. Copyright

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