Volcanic ash characterization and impact assessment during the 2024 Mt. Kanlaon Eruption

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Abstract: Mt. Kanlaon erupted on December 9, 2024, causing an ashfall that affected the islands of Negros, Guimaras, and Panay in the central Philippines. As there are metropolitan areas in these islands, a major eruption will have a substantial effect on the population. We collected ash samples in three sample locations across the Negros (KV1-La Carlota City, KV2- Bacolod City) and Panay islands (KV3-Miagao, Iloilo). We employed SEM-EDS analysis to characterize and analyze the elemental composition of the ash samples. We also combined the resulting data with the particulate matter concentration, volcanic explosivity, and prevailing weather conditions during the eruption to create an impact assessment index for the eruption. The results conform to the general observations where there is a bigger impact in the sites closer to the volcano.

Key Words: Volcanic Ash, Impact Assessment, Mount Kanlaon, SEM, LS-SVM

1. INTRODUCTION

Mt. Kanlaon is one of the 24 active volcanoes being monitored by the Philippine Institute of Volcanology and Seismology (Phivolcs). Located at the northern part of Negros Island (10.41129 N, 123.13243 E), it is sandwiched between the two provinces of Negros Occidental and Negros Oriental. The fertile soil around Mt. Kanlaon and in the nearby areas led to the rise of the sugarcane industry in Negros island. Several towns emerged around this area, such as Bago City, La Carlota City, Murcia, and La Castellana. 34 kilometers NW of the volcano is Bacolod City, a major metropolis in the Negros Island.

On 3:03 PM of December 9, 2024, Mt. Kanlaon erupted for almost four minutes, throwing an ash plume that rose 4,000 meters above sea level. The winds carried the ash WNW, causing ashfall in the islands of Negros, Guimaras, and Panay. Ashfall warning were raised from the nearby towns of Bago City in Negros Occidental down to Miagao, a town in Iloilo province, Panay Island, 101.5 kilometers WNW of Mt. Kanlaon (Philippine Institute of Volcanology and Seismology, 2024).

As it is near a regional metropolitan area (Bacolod city), a major eruption will have an outsized impact on the health of the nearby population. The health risks from the eruptions mainly come from airborne emissions: (1) sulfur compounds and other gases (2) fine particulate ash (containing PM2.5 or smaller particles) that contain heavy metals such as lead (Stewart, C., et al. ,2022). Volcanic eruptions produce considerable amounts of PM2.5 ash particles that pose health risk beyond respiratory tract problems (Feng, S., Gao, D., Liao, F., Zhou, F., & Wang, X., 2016). Additionally, they contain heavy metals and can mix and pollute water sources near the volcano and in the areas where ashfall occurred.

We looked at the elemental and morphological structures of ash samples we gathered from the 2024 Mt. Kanlaon eruption. We also made an attempt to streamline the impact assessment process by employing a Least Squares-Support Vector Machine (LS-SVM) algorithm (Leong et al., 2020) to calculate the impact of the eruption to a location, considering different factors such as distance, weather, etc.

2. METHODOLOGY

The ash samples from the 2024 Mt. Kanlaon eruption were collected on around 7:00 PM of December 9, 2024 as the wind brought the ash WNW from Negros to the nearby Panay island. The sample locations are listed in Table 1 while Figure 1 shows the maps of the locations of the sample locations for both eruptions. One sample was taken from each of these sites.

Table 1. Sample locations and Land Use classifications

Code	Sample Locations	Coordinates	Land Use
KV1	La Carlota City	10° 25' 23.088" N 122°54' 56.448" E	Residential, Commercial
KV2	Bacolod City	10° 38' 23.964" N 122° 56' 24.432" E	Residential, Commercial
KV3	Miagao, Iloilo	10° 38' 47.22" N 122° 13' 59.52" E	Residential, Commercial

There are three sample locations used for this study which includes KV1- La Carlota city (N = 4), KV2 – Bacolod city (N= 3), and KV3 – Miagao, Iloilo (N =3), where N is the number of samples. Each volcanic ash samples were collected within the 1m x 1 m area at the provided coordinates.

2.1 Mt. Kanlaon Ash Characterization

The volcanic ash samples were carefully placed on a 12mm diameter aluminum SEM stub and secured with double-sided conductive tape. The ashes were pressed on carbon tape using a surgical blade. The excess ashes were removed using a rubber bulb-air pump dust blower. The specimens were analyzed using a JEOL model JSM IT500HR/ LA, with a 3kV acceleration voltage, probe current of 35pA, and a working distance of (WD) approximately 10mm. An Energy Dispersive X-Ray spectrometry (EDS) was used to identify the elements of the volcano as specimens. In order to efficiently detect the elements, the acceleration voltage was increased to 15kV during EDS analysis.

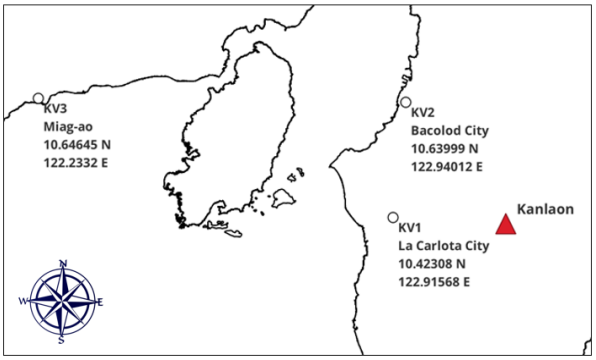


Figure 1. Sample locations for the 2024 Mt. Kanlaon eruption.

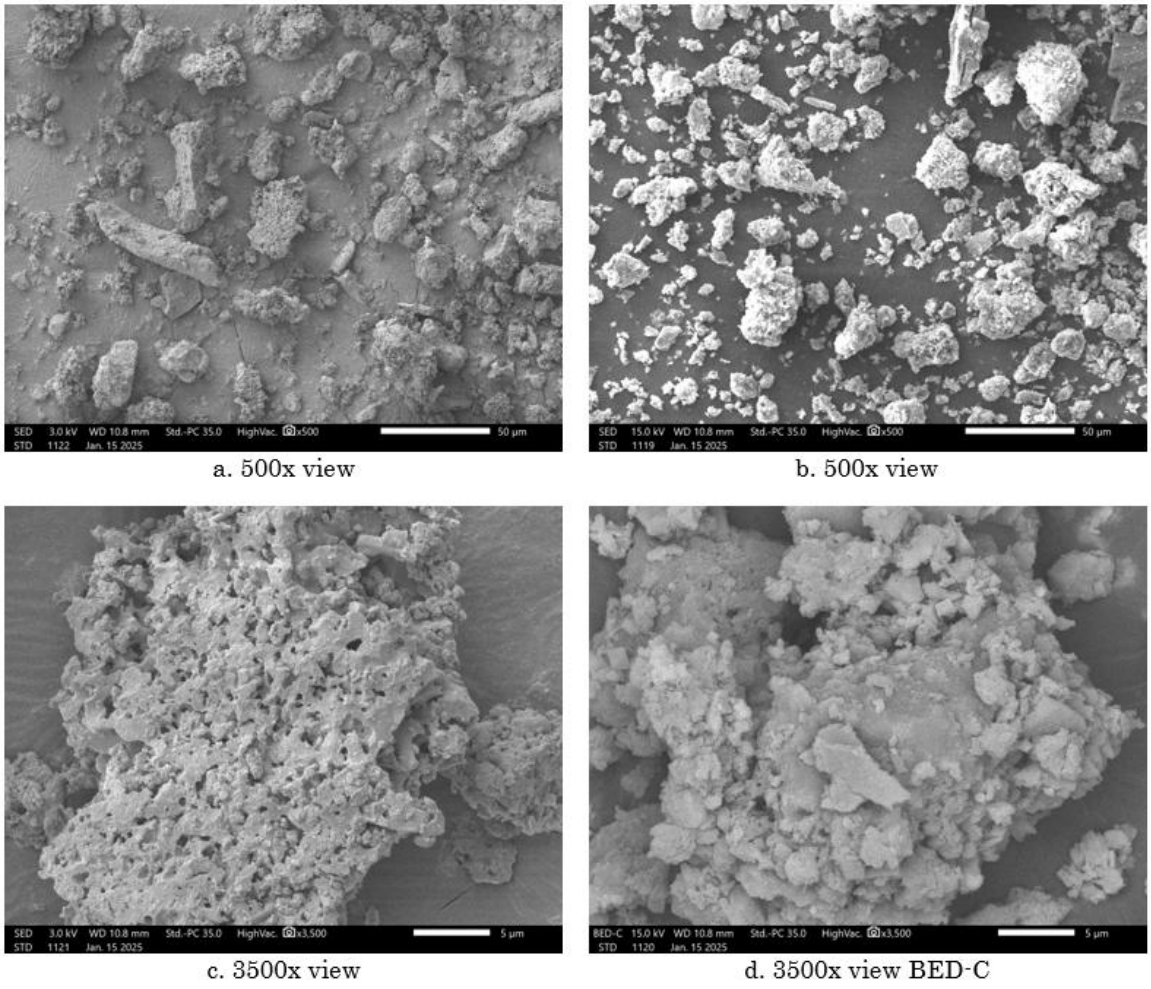
2.2 Air quality during eruption

Weather and particulate matter (PM) measurements were recorded during the Mt. Kanlaon eruption. Weather data such as air temperature, relative humidity, dew point and wind speed were collected (https://www.wunderground.com/) to discuss patterns from different sample locations. Portable PM sensors were deployed to measure different PM sizes such as PM 1, 2.5 and PM 10.

2.3 Volcanic Explosivity Index (VEI)

According to Newhall and Self (1982), a primary quantitative criterion for assigning a VEI is the volume of erupted ash. It is a scale that describes the size of explosive volcanic eruptions based on magnitude and intensity. The numerical scale (from 0

to 8) is a logarithmic scale, and is generally analogous to the Richter and other magnitude scales for the size of earthquakes (USGS, n.d.).



a. 500x view b. 500x view

c. 3500x view d. 3500x view BED-C

Figure 2. SEM photos of the ash sample from Miagao

2.4 Impact Assessment Index (IAI)

Using a developed Impact Assessment Index with least squares support vector machine algorithm, the equation is shown below.

IAI=(VEI×0.40)+(Weather×0.20)+(Elemental×0.25)+(PM×0.15)

The weight distribution shows 40% of the IAI is based on VEI, 20% is based on weather data which consist of air temperature, wind speed, and relative humidity (%), 25% is on elemental composition based on the SEM-EDS analysis, and 15% is based on the PM sizes such as PM2.5, and PM10. Once the IAI is calculated, the algorithm helps in the decision-making based on the following criteria:

- **0 - 0.3:** Low impact, minimal disruption.
- **0.3 - 0.6:** Moderate impact, some disruptions to health, environment, and infrastructure.
- **0.6 - 1.0:** High impact, significant disruption to human health, environment, and infrastructure.

Table 2. Elemental composition (mg/kg) of ash from the 2024 Mt. Kanlaon eruption, gathered from three locations

	Location								
Element	KV1 (mg/m³)	KV2 (mg/m³)	KV3 (mg/m³)	Max (mg/m³)	Min (mg/m³)	Mean (mg/m³)	Median (mg/m³)	SD	CV
C	7.070	6.942	2.525	7.070	2.525	5.513	6.942	2.588	0.469
O	8.917	3.107	1.179	8.917	1.179	4.401	3.107	4.028	0.915
Na	6.985	4.009	0.357	6.985	0.357	3.784	4.009	3.320	0.877
Mg	4.042	2.516	0.158	4.042	0.158	2.239	2.516	1.957	0.874
Al	5.605	3.996	7.901	7.901	3.996	5.834	5.605	1.963	0.336
Si	6.255	4.581	3.850	6.255	3.850	4.895	4.581	1.233	0.252
S	2.085	2.929	0.577	2.929	0.577	1.864	2.085	1.191	0.639
K	3.064	3.191	0.722	3.191	0.722	2.326	3.064	1.390	0.598
Ca	3.404	2.103	0.419	3.404	0.419	1.975	2.103	1.496	0.758
Fe	13.276	15.882	5.372	15.882	5.372	11.510	13.276	5.473	0.475

3. RESULTS AND DISCUSSION

3.1 Mt. Kanlaon Ash Characterization

As Miagao is relatively far from Mt. Kanlaon (located around 101 kilometers away), the ash sample from Miagao was analyzed for morphological assessment. Figure 3a and 3b shows two images of different portions of the ash sample from Miagao. Upon first look, a significant amount of PM 2.5 or smaller particles can be seen. These particles pose a significant respiratory risk, especially as the smaller particles are difficult to filter using known practical methods.

The ash samples are a mixture of sharp-edged particles and sponge-like particles. Figure 3c shows a close-up of Figure 3a. It shows an ash particle with vesicles, making it sponge-like. This means the ash could either be made of pumice or scoria. Figure 3d shows a BED-C image of a different part of the sample, showing aggregation of smaller particles to form a bigger one.

Table 2 shows the elemental composition of the ash samples from the Kanlaon eruption determined through EDS. The S content in the KV3 (Miagao) sample is lower than that of KV1 (La Carlota). This is expected as Miagao is farther from Kanlaon than La Carlota. However, the sample in KV2 (Bacolod City) is higher than that of KV1 (La Carlota City). This may be due to the urban nature of Bacolod City, where vehicle exhaust contains a significant number of sulfuric compounds. There is also higher Al content in the KV3 sample than in both KV1 and KV2 samples, implying a different source of Al for the KV3 sample.

3.2 Impact Assessment Index

The ash column during December 9, 2024 Mt. Kanlaon eruption was reported to reach 4 kilometers

above the vent. The eruption explosivity is thus rated at VEI 2 (column height is from 1-5 kilometers from the vent).

Table 3 shows the summary of the Weather and PM data collected during the Mt. Kanlaon eruption in all sample locations. Higher PM 2.5 data are collected on KV1 and KV2 sample locations which are caused by the eruption. On the other hand, the PM data collected from the KV3 sample station is higher compared to regular days. Overall, the collected PM values are within the Philippine and WHO guideline values for PM 2.5 and PM 10 (Cadondon et al., 2024).

Table 3. Mean distribution of Weather and PM data

	Location		
	KV1	KV2	KV3
PM (µg/m3) data			
PM 2.5	28.12	24.5	4.5
PM 10	16.7	14	12.6
Weather data			
Temperature (oC)	28.5	28	29
Humidity (%)	88	90	92
Wind Speed (mi/h)	9.5	7.7	11.2

From the collected values, indices were created based on weather, PM, VEI, and elemental composition (Aydin, 2023). Table 4 shows the summary of the indices computed.

Table 4. IAI for all sample locations

Location	VEI	Weather	Elemental	PM	IAI Norm.	Impact
KV1	2	44.6	6.32	22.65	0.67	High
KV2	2	43.71	5.65	20.35	0.73	High
KV3	2	48.86	3.07	6.93	0.03	Low

Using the LS-SVM algorithm, we added several factors such as sample location, distance to Mt. Kanlaon, land use, and urban density. The enhanced IAI values are shown in Figure 3.

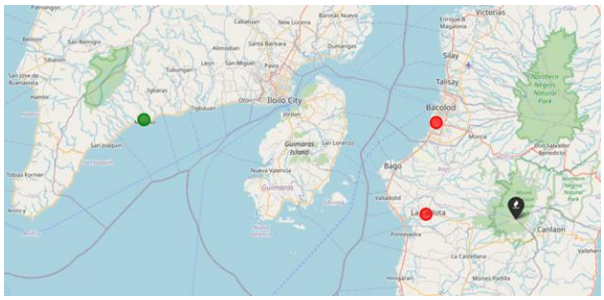


Figure 3. IAI values of the sample locations. Red - high impact; yellow - medium impact; green - low impact.

The results of the enhanced IAI method makes sense: the sample locations KV1 and KV2 are given a higher score because of their proximity to Mt. Kanlaon. KV3 got a lower score than KV1 and KV2 but did not get a score of 0 because KV3 also experienced an ashfall due to the eruption. The developed IAI showed significant results in assessing the impact of Mt. Kanlaon eruption. The model can be further employed to different eruptions in the Philippines and other Asian countries. There were limitations associated with the index such as the VEI which can be further modified by including elevation and historical data. In the future, we plan to include a health assessment index (Mueller et al., 2020) in the total IAI to further include age brackets, vulnerability and possible diseases that can be derived from such volcanic activities. These results can be used to further assess possible effects of future hazards.

4. CONCLUSIONS

The 2024 Mt. Kanlaon eruption is a VEI 2 eruption that produced a significant amount of ash, affecting the western towns of the Negros Island and reaching the towns of the Panay Island such as

Miagao. The ash carries compounds, both from its original composition and the ones present in the air, that pose health risk to the population affected. An attempt was made to calculate the impact of the eruption, which does conform to the observations where there is a bigger impact in the nearer sites than in the farther sites. Further studies are needed to create a full picture of the impact of the eruption and also to improve the impact assessment tool we developed.

5. ACKNOWLEDGMENTS

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