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RESEARCH ARTICLE OPEN ACCESS

Managing Volcanic Multi-Hazards: Lipa City CDRRMO'S Preparedness and Response to Base Surge, Sulfur Dioxide Emissions, and Landslides

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Abstract:

The study was designed as an action plan to enhance preparedness and response to volcanic hazards in Lipa City. It focused on the risks posed by volcanic events such as base surges, airborne sulfur dioxide, and landslides, which threaten residents, property, and infrastructure, particularly affecting children, the elderly, and those with pre-existing medical conditions. This plan addresses gaps in the city's current disaster management by combining preventive, protective, and responsive strategies. It emphasizes environmental monitoring, community training in first aid and disaster response, public awareness campaigns, simulation drills, and efficient communication systems to ensure timely and coordinated actions during emergencies. Key interventions include mobile command posts, designated evacuation routes, livelihood recovery programs, and psycho-social support for affected residents.

Keywords — **Volcanic Hazards, Disaster Preparedness, Lipa City, Risk Reduction, Emergency Response**

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I. INTRODUCTION

The Philippines is one of the most disaster-prone countries in the world because of its location along the Pacific Ring of Fire [14]. This zone is marked by frequent earthquakes and volcanic eruptions. Out of about 300 volcanoes in the country, 24 are considered active by the Philippine Institute of Volcanology and Seismology (PHIVOLCS). These include Mayon, Pinatubo, Kanlaon, Bulusan, Hibok-Hibok, and Taal. Each has produced eruptions with serious impacts, such as displacement of communities, fatalities, and long-term environmental change [8].

Among these, Taal Volcano is one of the most dangerous. Located inside Taal Lake, it has a history of violent eruptions. The 1911 eruption killed 1,334 people, while the 1965 eruption generated a deadly base surge that flattened villages and caused about 200 deaths [4]. More recently, the January 2020 eruption displaced more than 376,000 individuals and caused over ₱3.4 billion in agricultural losses. During this event, PHIVOLCS measured SO_2 emissions reaching 5,299 tons per day, while ashfall thickness in Lipa reached up to 2 mm, enough to damage roofs, clog drainage, and reduce visibility.

Taal Volcano Island has a land area of 2,500 hectares, with its highest point rising 311 meters above sea level at the southwest rim of the main crater. The volcano sits within the 117-square-kilometer Taal Caldera, now occupied by Taal Lake. Historically, the 1754 eruption sealed off the Balayan Bay outlet, transforming the saltwater channel into a freshwater lake that submerged several towns.

TABLE I
ACTIVE VOLCANOES IN THE PHILIPPINES

Volcano	Location	Notable Eruptions	Impacts
Mayon	Albay, Bicol	Over 50 eruptions in 400 years	Lava flows, pyroclastic materials, destruction of farms and towns
Pinatubo	Zambales	1991 eruption	Released 20M tons of SO_2, cooled global climate, massive lahar flows
Kanlaon	Negros Island	Frequent small eruptions	Minor damage but highly unpredictable
Bulusan	Sorsogon	Multiple ash explosions	Sudden disruptions in surrounding areas
Hibok-Hibok	Camiguin	1951 eruption	More than 500 deaths, heavy displacement
Taal	Batangas	33 eruptions since 1572	Large-scale destruction, repeated evacuations

Lipa City, with a population of approximately 340,000, lies roughly 30 km from Taal's main crater. While most of the city is outside the 14-kilometer permanent danger zone, some barangays fall within the extended hazard influence, making them highly vulnerable to volcanic effects such as ashfall, airborne SO_2, and slope instability [1]. Factors contributing to this vulnerability include wind direction during eruptions, topography, and population density.

The high-risk barangays identified are Halang, Duhatan, Bulaklakan, Bagong Pook, and Tangway. Together, these barangays host over 8,300 residents, representing about 2.5% of Lipa City's total population. Their exposure reflects realistic worst-case scenarios based on PHIVOLCS hazard maps and previous eruption patterns, particularly concerning ash dispersion, gas exposure, and landslide susceptibility during heavy rainfall [2].

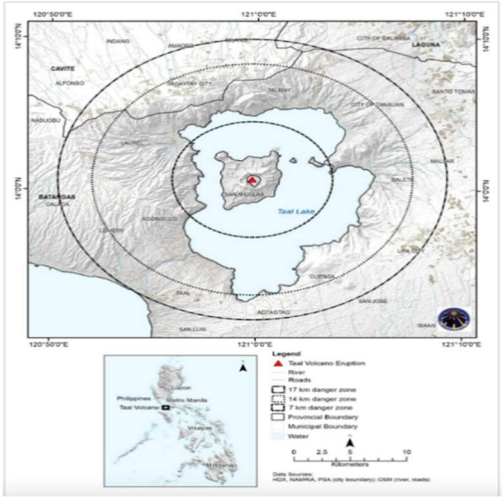

Fig. 1. Location Map of Taal Volcano and Affected Areas

TABLE II
HISTORICAL ERUPTIONS OF TAAL VOLCANO
(SELECTED YEARS)

Historical Eruption Centers	
Binitiang Malaki	1767, 1715 eruptions
Binintiang Munti	1709, 1731 eruptions
Pira-piraso	1731 eruption
Off Calauit	1716 eruption
Mt. Tabaro	1965-1970, 1976-1977 eruptions

II. METHODOLOGIES

This study used a mixed-method approach combining descriptive and exploratory methods, supported by documentary analysis, to assess Lipa City's preparedness and response to volcanic hazards such as base surges, sulfur dioxide, and landslides. Surveys and structured questionnaires were conducted among 68 residents from five high-risk barangays and 9 DRRM staff to measure awareness, preparedness, and health risks, while site visits and document reviews provided insights into evacuation centers, emergency resources, and past disaster responses. Data were analyzed using Microsoft Excel, and ethical protocols, including informed consent and confidentiality, were strictly observed, ensuring reliable findings on community readiness, institutional response, and health impacts.

Situational Analysis

Lipa City, located in the province of Batangas, lies within the influence zone of Taal

Volcano, one of the most active volcanoes in the Philippines [3]. Situated approximately 14 kilometers southeast of Taal Volcano, the city remains highly exposed to the volcano's hazardous emissions and secondary effects. The eruption of Taal on January 12, 2020, severely impacted communities across CALABARZON, resulting in widespread ashfall, sulfur dioxide exposure, and ground movement. Several barangays in Lipa City, particularly Halang, Duhatan, Bulaklakan, Bagong Pook, and Tangway were identified as high-risk areas based on PHIVOLCS hazard maps and local government (LGU) risk classifications, which consider proximity to the volcano, topographic features, and previous exposure to volcanic materials. These areas face recurring threats, as shown by past eruptions in 1749, 1754, 1911, 1965,1977, and 2020, from base surges, airborne sulfur dioxide, and secondary landslides triggered by heavy rainfall and ash accumulation.

Health records confirmed a high prevalence of Acute Upper Respiratory Infections (AURI) before and after the eruption. The Field Health Service Information System (FHSIS) reported 259 AURI cases in 2019, with the most affected groups being children aged five to nine years, followed by those aged one to four and infants below one year (example of a standard paper in [5]). In 2020, the number of recorded cases dropped to 56, primarily because of strict lockdown measures during covid-19 pandemic, when residents avoided visiting health centers and routine consultations were deferred due to movement restrictions and fear of infection. In succeeding year, however, the number of reported cases rose dramatically, by 2022 a total of 9,463 AURI cases were recorded, an increase of 16,804% from 2020 to 2022. Health authorities suggested that this sharp increase was partly due to greater health-seeking behavior among citizens, many of whom visited health centers believing their symptoms might be related to covid-19 [6]. Regardless, these figures highlight the persistent vulnerability of children and other sensitive populations to air quality hazards associated with volcanic activity.

TABLE III
REPORTED CASES OF ACUTE UPPER RESPIRATORY INFECTIONS (AURI) BY AGE GROUP, LIPA CITY (2019–2022)

Year	Under 1 Year of Age	1–4 Years Old	5–9 Years Old	Total (Under 1-70 Above)
2019	72	73	114	259
2020	24	12	20	56
2022	-	-	-	9463

Source: FHSIS Morbidity Report (City Health Office of Lipa, 2019-2022)

Result of the Conducted Survey

The survey was conducted through face-to-face interviews with the support and approval of the Barangay Captains and barangay officials. The researcher worked alongside local staff to distribute and collect the questionnaires, ensuring that the study's purpose, goals, and procedures were clearly explained to all participants. This approach helped guarantee that the data collection was efficient, ethical, and respectful of the respondents.

Part I. Demographic Profile

This section presents the profile of the respondents from the five selected barangays of Lipa City. Understanding who participated gives context to the results and shows the perspectives of the people most affected by volcanic hazards.

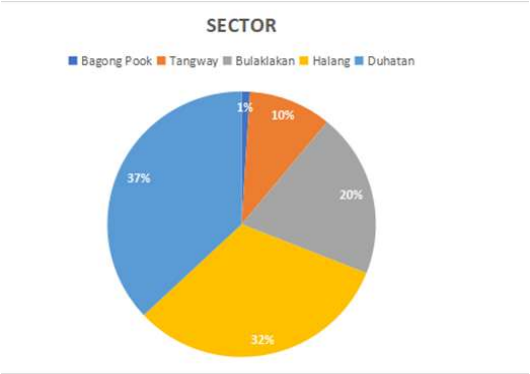

Fig. 2. Respondents by Sector

The figure illustrates the distribution of respondents across barangays. Halang and Duhatan contributed most participants, reflecting their larger populations. Smaller communities, like Bagong Pook, had fewer respondents but were included to ensure representation across all high-risk areas.

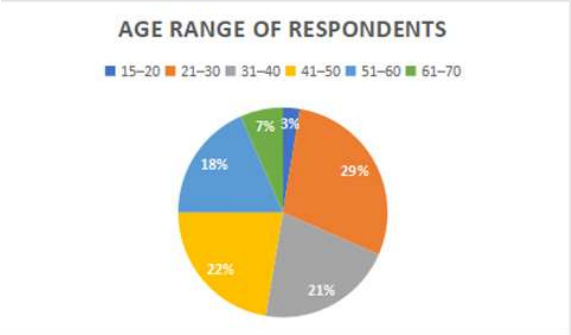

Fig. 3. Age Range of Respondents

Figure 3 presents the age distribution of the 77 respondents. The results show a concentration of participants within the young adult and adult age groups. According to the World Health Organization's general life stage classification, young adults are those between 20 and 24 years old, while adults range from 25 to 59 years old. The data indicate that the 21–30 age group forms the largest portion, representing 28.57% of the total respondents. This is followed by the 41–50 age group with 22.08% and the 31–40 age group with 20.78%. The 51–60 group accounts for 18.18%, while older respondents aged 61–70 and 71–80 make up smaller portions at 6.49% and 1.30%, respectively. Meanwhile, those in the 15–20 age range represent 2.60% of the population.

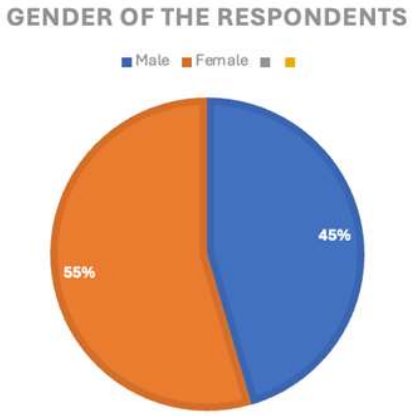

Fig. 4. Gender of the Respondents

Figure 4 illustrates the gender composition of the 77 respondents. The data show a higher proportion of female participants, with 42 individuals representing 54.55% of the total, while males account for 35 respondents or 45.45%. This distribution indicates a relatively balanced participation of both sexes, though slightly favoring females.

The predominance of female respondents reflect their active involvement in community matters, household management, and health-related decision-making, making them key informants for understanding local preparedness and response to volcanic hazards [7]. Male respondents, on the other hand, contribute perspectives related to labor, disaster response roles, and community protection activities. The inclusion of both genders ensures that the study captures diverse viewpoints, providing a comprehensive understanding of health risks, awareness, and safety practices in the high-risk barangays [11].

Part 2. Basic Information

TABLE IV
BASIC INFORMATION OF THE RESPONDENTS

Indicators	Frequency (Yes/No)		Percentage
1. There is an official DRRM focal person assigned in your barangay.	77	-	100%
2. The barangay has a prepared evacuation plan in case the volcano reaches an alert level.	77	-	100%
3. There is a clear communication or warning system in place for volcanic hazards.	77	-	100%
4. You have been informed via text alerts or social media about volcanic hazards.	77	-	100%
5. There is a designated area in your barangay for emergency assembly.	77	-	100%
6. The barangay hall has a stockpile of relief goods or emergency supplies.	77	-	100%
7. The barangay implements programs for health and safety during volcanic events.	77	-	100%
8. There are youth volunteers or community groups that assist during disasters.	77	-	100%
9. You have received assistance or coordination from the Lipa City CDRRMO.	77	-	100%
10. You wish to have additional training on disaster preparedness and response.	77	-	100%

The results of the survey show a remarkable level of preparedness and awareness

among respondents in the five high-risk barangays of Lipa City. All 77 participants answered "Yes" to every indicator, reflecting full acknowledgment of the existing disaster risk reduction and management (DRRM) measures in their communities.

Finally, all participants expressed interest in additional training on disaster preparedness and response, demonstrating a proactive attitude toward enhancing personal and community safety [9].

The findings indicate that Lipa City's high-risk barangays are well-prepared in terms of planning, communication, and community participation, while residents remain eager to strengthen their knowledge and skills in disaster management [11].

Part 3. Awareness and Knowledge

TABLE V
RESPONDENTS' AWARENESS AND KNOWLEDGE OF VOLCANIC MULTI-HAZARDS

	Questions	WM	VI	Rank
1	I am aware of the hazards caused by base surge, sulfur dioxide, and landslides.	4.05	Agree	4
2	I have received clear information from authorities about volcanic multi-hazards.	3.99	Agree	5
3	I understand the warning signs to watch for before and during a volcanic eruption.	4.11	Agree	1.5
4	I know the correct actions to take during a multi-hazard event.	4.11	Agree	1.5
5	I have participated in trainings, drills, or community programs related to disaster preparedness.	4.07	Agree	3
	Weighted Mean	**4.06**	**Agree**	

Legend: 4.21 – 5.00 Strongly Agree, 3.41-4.20 Agree, 2.61-3.40 Neutral, 1.81-2.60 Disagree, 1.00-1.80 Strongly Disagree

Table 5 presents the respondents' awareness and knowledge regarding volcanic multi-hazards in Lipa City which indicated the highest weighted mean of 4.11 both from items 3 & 4 which states that respondents has enough knowledge regarding volcanic multi-hazards.

The overall weighted mean of 4.06 indicates that participants generally agree that they are knowledgeable and aware of the risks associated with base surge, sulfur dioxide, and landslides.

TABLE VI
HEALTH CONDITIONS AND EXPOSURE TO VOLCANIC HAZARDS AMONG RESPONDENTS

	Questions	WM	VI	Rank
1	I have experienced respiratory symptoms (e.g., coughing, shortness of breath, chest pain) due to ash or sulfur dioxide.	3.68	Agree	2
2	My pre-existing health condition (e.g., asthma, bronchitis) worsened after a volcanic eruption.	3.37	Neutral	5
3	Exposure to ash or sulfur dioxide caused me stress or anxiety.	3.56	Agree	4
4	My family experienced difficulties accessing medical services during an eruption.	3.64	Agree	3
5	I used protective equipment (mask, goggles, etc.) during volcanic hazards.	4.05	Agree	1
	Weighted Mean	**3.66**	Agree	

Legend: 4.21 – 5.00 Strongly Agree, 3.41-4.20 Agree, 2.61-3.40 Neutral, 1.81-2.60 Disagree, 1.00-1.80 Strongly Disagree

Table 6 illustrates the respondents' health experiences and exposure to volcanic hazards in Lipa City. The overall weighted mean of 3.66 indicates general agreement that volcanic activity impacts the health and well-being of residents, particularly through respiratory symptoms and related challenges.

Part 5. Preparedness and Safety

TABLE VII
HOUSEHOLD AND COMMUNITY PREPAREDNESS AND SAFETY MEASURES

	Questions	WM	VI	Rank
1	My family has a prepared emergency kit (medicines, food, water, flashlight, etc.).	4.04	Agree	4.5
2	I know the evacuation routes and safe locations in our barangay.	4.19	Agree	1
3	My family has a communication plan in case we get separated.	4.04	Agree	4.5
4	There are enough evacuation centers in our area that residents can easily reach.	4.14	Agree	3
5	I trust the ability of our barangay and the Lipa City CDRRMO to respond to multi-hazards.	4.18	Agree	2
	Weighted Mean	**4.12**	Agree	

Legend: 4.21 – 5.00 Strongly Agree, 3.41-4.20 Agree, 2.61-3.40 Neutral, 1.81-2.60 Disagree, 1.00-1.80 Strongly Disagree

Table 7 presents the preparedness and safety measures adopted by households and the community in response to volcanic hazards. The overall weighted mean of 4.12 indicates that respondents generally agree that both families and the barangay demonstrate a strong level of preparedness for multi-hazard events.

Overall, the findings suggest that while there is a high level of preparedness and safety awareness among respondents, continuous community education and regular drills can further strengthen readiness and confidence in facing volcanic hazards [12],[13].

Part 6. Environmental and Social Impacts

TABLE VIII
PERCEIVED ENVIRONMENTAL AND SOCIAL IMPACTS OF VOLCANIC HAZARDS

	Questions	WM	VI	Rank
1	Volcanic hazards have a significant impact on the air and water quality in our community.	4.05	Agree	2
2	Our livelihood is affected during disasters (e.g., farming, fishing, business).	3.86	Agree	5
3	Children's education is disrupted during strong eruptions and hazards.	4.17	Agree	1
4	Our community has experienced financial loss and family displacement due to disasters.	3.88	Agree	4
5	We receive sufficient assistance from the government and other organizations after a disaster.	3.99	Agree	3
	Weighted Mean	**3.99**	Agree	

Legend: 4.21 – 5.00 Strongly Agree, 3.41-4.20 Agree, 2.61-3.40 Neutral, 1.81-2.60 Disagree, 1.00-1.80 Strongly Disagree

Table 8 presents respondents' perceptions of the environmental and social impacts caused by volcanic hazards in their community. The overall weighted mean of 3.99 indicates that respondents generally agree that volcanic events significantly affect both the environment and the social well-being of residents.

Overall, the results highlight the intertwined nature of environmental and social consequences of volcanic hazards [15]. They indicate the importance of integrated disaster risk reduction strategies that protect health, livelihoods, education, and community resources.

Pestel Analysis

PESTEL analysis examines external factors affecting disaster risk reduction and management (DRRM) across six dimensions: Political, Economic, Social, Technological, Environmental, and Legal, helping barangays plan and respond effectively to volcanic hazards.

Political

Local governance is stable, with DRRM focal persons and committees ensuring coordination, community engagement, and resource mobilization. Political turnover may disrupt continuity, so maintaining institutional knowledge is crucial.

Economic

Residents depend on agriculture, small businesses, and fisheries, which are vulnerable to eruptions. Barangay resources and preparedness efforts improve resilience, but livelihood protection and financial strategies are needed to support recovery.

Social

Communities show strong cohesion and active participation in drills and trainings. Vulnerable groups like children, elderly, and those with health conditions require additional support to ensure equitable access to healthcare and protective measures.

Technological

Communication systems and protective equipment aid preparedness, but gaps remain in advanced early warning systems and monitoring infrastructure. Public-private partnerships can enhance technological resources and emergency response efficiency.

Environmental

Volcanic hazards impact air, water, agriculture, and daily life, affecting livelihoods and education. Integrated hazard monitoring, environmental protection, and community education are needed to reduce socio-environmental risks.

Legal

DRRM is supported by ordinances and RA 10121, providing frameworks for plans, evacuation, and relief. Coordination with private stakeholders and continuous policy updates are

needed to ensure compliance and strengthen response.

SWOC Analysis

Strengths

Disaster Prevention & Mitigation: DRRM focal persons are designated; barangays have clear evacuation plans and communication systems; residents are aware of volcanic risks.

Preparedness: Active community participation in drills and trainings; households maintain emergency kits and communication plans; evacuation centers are accessible.

Response: Protective measures like masks and goggles are used; residents trust barangay and city response teams.

Rehabilitation & Recovery: Local authorities provide support and assistance during recovery.

Weaknesses

Prevention & Mitigation: Risk communication from authorities could be improved.

Preparedness: Training coverage is limited; more comprehensive drills are needed.

Response: Access to healthcare during eruptions is challenging.

Rehabilitation & Recovery: Socio-economic vulnerabilities such as livelihood loss and displacement remain.

External Assessment: Opportunities and Challenges

Opportunities

Prevention & Mitigation: Partnerships with schools, NGOs, and industries; expand public education campaigns.

Preparedness: More realistic drills and family-level preparedness programs.

Response: Resource sharing and coordination with neighboring barangays and private sectors.

Rehabilitation & Recovery: Community-based programs to restore livelihoods, education, and housing.

Challenges

Prevention & Mitigation: Rapid urbanization and environmental changes may create new hazards.

Preparedness: Low public compliance in drills and protocols.

Response: High-impact volcanic events with simultaneous health and social impacts may overwhelm resources.

Rehabilitation & Recovery: Economic losses, school interruptions, and displacement require timely support systems.

III. GOALS AND OBJECTIVES

The following goals and objectives outline a comprehensive framework for disaster risk reduction and management in Lipa City, focusing on preventive, preparatory, responsive, and recovery measures to address volcanic multi-hazards such as base surges, sulfur dioxide emissions, and landslides.

A. Disaster Prevention and Mitigation

Goal 1: Minimize risks and damages caused by base surge, SO_2 emissions, and landslides through preventive measures and risk reduction strategies.

Objectives:

1.1 To identify, map, and regularly update multi-hazard zones prone to base surge, SO_2 exposure, and landslides every six months.

1.2 To install and maintain early warning devices and signages in high-risk barangays within one year.

1.3 To strengthen environmental monitoring systems for air quality, soil stability, and volcanic activity semi-annually.

1.4 To implement community-based hazard mitigation projects such as tree planting and slope protection annually.

B. Disaster Preparedness

Goal 2: Enhance community awareness, readiness, and coordination in managing volcanic multi-hazards before, during, and after an eruption.

Objectives:

2.1 To conduct quarterly public information drives and simulation drills on evacuation and safety procedures.

2.2 To train barangay DRRM teams, volunteers, and health workers in responding to base surge, SO_2 inhalation, and landslide emergencies semi-annually.

2.3 To develop a barangay-level communication plan using text alerts, social media, and radio updates for timely warnings.

2.4 To strengthen partnerships with schools, religious groups, and civic organizations for community-based preparedness programs annually.

C. Disaster Response

Goal 3: Ensure fast, coordinated, and effective response operations to protect lives and reduce the impact of volcanic multi-hazards.

Objectives:

3.1 To establish mobile command posts and emergency health stations in safe zones during eruption events as needed.

3.2 To conduct rapid assessment and provide immediate rescue, relief, and medical assistance in affected areas during emergencies.

3.3 To ensure safe evacuation and transport of residents, prioritizing children, elderly, and persons with disabilities, during high-risk volcanic activity.

3.4 To maintain real-time coordination between the Lipa City CDRRMO and barangay DRRM committees throughout the response phase.

D. Disaster Rehabilitation and Recovery

Goal 4: Restore and strengthen community resilience through long-term rehabilitation, livelihood recovery, and infrastructure rebuilding.

Objectives:

4.1 To rehabilitate damaged infrastructure such as roads, drainage systems, and evacuation centers within one year after a disaster.

4.2 To implement livelihood assistance and recovery programs for affected families within six months post-eruption.

4.3 To integrate lessons learned from disaster experiences into updated DRRM and land-use plans annually.

4.4 To promote psychosocial support and community healing activities for affected residents as part of the recovery process.

IV. MONITORING AND EVALUATION

The implementation of the disaster risk reduction and management goals and objectives will be continuously monitored and evaluated to ensure effectiveness and timely adjustments. Key indicators such as the number of hazard maps updated, early warning devices installed, community drills conducted, response times during emergencies, and rehabilitation projects completed will be tracked regularly. Barangay DRRM committees, in coordination with the Lipa City CDRRMO, will conduct quarterly progress reviews and annual evaluations to assess achievements, identify gaps, and incorporate lessons learned into updated plans. Feedback from community members, volunteers, and DRRM staff will be collected through surveys and consultations to measure satisfaction, awareness, and preparedness levels. This systematic M&E process will support accountability, improve decision-making, and strengthen the city's capacity to reduce risks and respond effectively to volcanic multi-hazards.

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