OVERVIEW OF POTENTIAL IMPACT OF ERUPTIONS ON VOLCANIC ISLANDS
(Global approaches for volcanic risk mitigation)

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Idyllic though they may seem, the islands have not escaped global trends of increasing urbanization and occupation of marginal lands resulting in higher levels of vulnerability and exposure to more risk. From 1976 until today more than 200.000 people have been displaced due to a volcanic crisis in the islands. People displacement duration varied from days to years. When populations of volcanic islands are displaced for long terms, economic and personal disruption are increased. The economies of many volcanic islands in the world are underpinned by tourism, the very nature of which exposes the infrastructure and investments to coastal flooding from direct impact of a volcanic eruption and possibly occurrence of tsunamis. Exploitation of natural resources for tourism and development of coastal areas all increase vulnerability.
Several particular aspects should be considered with regard of volcanic islands :

- A volcanic islands represents only the summit part of a larger volcanic edifice rising up from the sea floor and inhabitants have to live closer the vent area than in the case of land volcanoes.
- Phreatomagmatic eruption take more important part in insular volcanoes than in land volcano
- Tsunamis which can occurs from volcanic landslide or new submarine vent near the island are more potentially dangerous than in land, because many inhabitants live near the coastal area

<u>Human and social impact reviews</u>

Living in a volcanic areas can affect the lives of people in both positive (soil fertility, beauty of volcanic landscape) and negative way (eruption). Any volcanic eruption, whatever its degree of violence, can dangerous to people in its neighbourhood. Large number of lives and large economic investments may therefore be at risk when an eruption occurs. Sometimes, when volcanic crisis occurs, evacuation can become necessary.
Evacuation in the face of volcanics hazards has one major difference when compared with evacuation from other natural hazards impacts, the duration is much less certain. When population are displaced personal social and economic disruptions are affecting the communities particularly in volcanic islands. Often, volcano islands are small territories in which the limit of acceptable risk must be necessity be set higher than in a large country where the evacuation from a single volcano has little or no social-economic impact. Long-duration evacuation could led to inevitable hardship and in some cases frustrations among the population.
However, in some cases, off-shore evacuation may be necessary for small volcanic islands at risk. Over the past centuries, temporary abandonment, particularly of islands, has occured on several occasions. For instance, an eruption on Bam (Papua-New Guinea), probably in the 1870's, resulted in abandonment of the island for several years. Similary, a series of severe eruptions between 1771 and 1786 caused Vulcano (Italy) to be left uninhabited for a number of years. At Santorini in 1925, sufficient people left the island as a result of the eruption.
During the 20th centuriesd, from 1973 to 2004, 17 major events from 14 island volcanoes in 7 countries necessitated large evacuation (Tableau 1) In the longer term, damage to productive assets could lead to a loss of output with reduced economic growth and declining standarts of living. The most recent example is the major evacuation of the South of the Montserrat island, including the capital town Plymouth, that took place in late August and December 1995. The soufriere Hills volcano is still active at the time of writing. Economic losses due to the eruption exceeded the GDP of the Montserrat island.

Years	Volcano	Number of evacued	causes
1973	Heymaey (iceland)	5000	Lava flows, tephra falls
1976	Soufrière Guadeloupe	72000	Phreatic explosions
1976	Karangetang (Ind.)	1800	Pyroclastic flows
1977	Karthala (Comores)	4000	Lava flows
1977	Piton de la Fournaise (Fr)	2500	Lava flows
1979	Soufriere St. Vincent	17000	Pyroclastic flows
1980	Gamalama (Ind.)	40000	Tephra falls, forest fire
1983	Myakejima (Japan)	1400	Explosions, lava flows
1983	Una Una – Colo (Ind)	7000	Explosions, Pyroclastic flows
1984	Karangetang (Ind.)	20000	Tephra falls, mudflows
1985	Sangeang Api (Ind.)	1240	Explosions, lava flows
1986	Oshima (Japan)	12200	Explosions, lava flows
1988	Banda Api (Ind.)	10000	Bombes, lava flows
1988	Makian (Ind.)	15.000	Explosions
1993	Karangetang (Ind.)	452	Ashfalls, lahars
1995	Fogo (Cape Verde)	1300	Ashfalls, lava flows
1995	Montserrat	7000	Explosions, pyroclastic flows
2000	Myakejima (Japan)	4000	Explosions, tephra falls

Number of displaced islands people from 1973 to 2004 – Data listed only evacuation of more 400 persons – H. Gaudru- SVE - 2004 - Source : GVN/GVP, OCHA, VRC, SVE

Historic fatalities

Since Year 1700 , 9 major eruptions from volcano island killed about 100.000 people. Direct mortality was caused by : Pyroclastics flows, lahars, landslides and indirect mortality by large tsunami. The Krakatau eruption in1883 was the most lethal, killing indirectly by induced tsunami about 36.000 people. The second in mortality is the Montagne Pelée (Martinique) in 1902 which killed about 29.000 persons by direct pyroclastic flows. Third, is the Tambora (Indonesia) large eruption in 1815 wich killed about 12.000 people by direct pyroclastic flows. Awu volcano in Indonesia generated most lethal lahars over the period (1701, 1856, 1892) with 7500 fatalities. Most recent fatalities from volcano island (Indonesia) was in 1979 when a tsunami induced by landslide occured on Illiwerung volcano (Indonesia) killed 539 people. Explosive activity accompanied by landslide at Paluweh volcano (Indonesia) generated a tsunami which killed 160 people on the coast.
During the past, lava flows were not caused large fatalities. A local legend report that a lava flows at the Aoba volcano (Vanuatu) caused many fatalities about 300 years ago (?) According to a report, main historic fatalities occured in Furnas (Azores) in 1808, when people attempting to save furniture remained too long in vicinity of advancing lave and about 8-10 died on the spot or a few day later (Smitsonian,, 1994)

Main potential hazards for volcanic islands

In addition to usual volcanic impacts in relation with eruption some particular phenomenas can potentially affect much more people living on small volcano islands such, pyroclastic flows, large phreatomagmatic explosion, flank collapses and tsunamis due to their smaller sizes and their marine environment.

Explosive eruption and fallout

As it is for most volcanoes, pyroclastic flows are the most lethal and destructive of all volcanic phenomena. Pyroclastic flows constitute a significant part of the activity of the circum-pacific subduction zone and the West-Indies islands. One of the most destructive example of pyroclastic flow is that which wiped ot the town of St.Pierre in Martinique island (french West-Indies) on 8 may 1902, killing 29.000 people. During the recent period, the Soufriere Hills volcano on Montserrat has been

producing recurrent major dome-building eruptions for nearly 9 years, with devastating pyroclastics flows and surges, and vulcanian explosive activity. Several thousand people remain on a land area of only 40 km2, attempting to live with the volcano, having suffered multiple fatalities in one big pyroclastic flow. Because their limited surface, volcanic islands could be severely affected by a such phenomena.
Due to the marine environment explosive activity can be very violent in a volcanic island. Phreatomagmatic volcanism which is a major type of explosive activity in different geological environment of magma type can seriously affected a small volcanic island. In the course of explosive volcanic activity such phreatomagmatic mechanisms frequently play some role. Not only in eruptions of tuff rings and tuff cones, but also in plinian events a significant phreatomagmatic phase may occur during decreasing or increasing magma production rate.
Larger fragments of volcanic material (bombs or rocks) can fall out quickly on the area close to the active crater and smaller fragments (lapilli, ash) can travel greater distances. Ash falls vary widely in volume and intensity and may occur simultaneoulsly or alternately with other eruptive phenomena such pyroclastic flows. In the neighbourhood on an erupting island volcano, heavy ash falls may cover a large part of the agricultural land rendering the land temporarily unworkable and may cause collapse of the roofs of houses. Dust in the air may take breathing difficult for both and animals. In August 2000, large eruption of the Miyakejima opened a long fracture located NW of the island, sucking a large amount of magma from the reservoir beneath the volcano causing important hydrovolcanic explosions accompanied by a pyroclastic flow that reached the sea. The island was partially evacuated. (S.Aramaki, 2001). Social and economic disturbance following a violent (and sometimes long-lived) eruption in volcanic island can be very important. (Montserrat, West Indies).

Flank collapse and tsunami hazards

Degradation of oceanic islands, apart erosion, is accomplished by many different of collapse process that may varie widely depending of the evolutionary stage : syneruptive and posteruptive collapse and variable transport collapse including debris avalanches and debris flows (H.Schmincke et al.2002). Results from a recent marine geophysical survey demonstrate the importance of the process of flank collapse in the in the growth and evolution of volcanoes along an island arc (C.Deplus et al. 2001). Other recent study of debris avalanche deposits reveal at least 10 flank collapses for the Decouverte-Soufriere volcano (Guadeloupe-West Indies) in the last 50.000 years, and at least 6 distinct events occured in the last 8500 ans. (J.C Komorowsky, Boudon et al., 2001)
Volcanic earthquakes frequently precede or accompany eruptions by themselves are rarely of sufficient magnitude or intensity to cause severe dommage, but they can induce partial volcano collapse. Volcanic debris avalanches generated by sliding of larger portions of volcanic cone are common. In recent years it has been recognised that an increasing number of volcanoes have experienced large lateral collapse. The hazard derive from the avalanches themselves, from landslide-triggered eruptive activity ranging from phreatic or magmatic explosion to powerful lateral blast. These avalanches are highly mobile and may not only bury tract of land but also cause devastating tidal waves if they advance into the sea. Volcano collapse represents one of the major potential hazard in the volcanic islands. Indeed , many volcanic cone within a marine environment can become unstable over the time and collapse into the sea to produce tsunamis that may be highly destructive in the coastal areas.

For instance, there have been five major lateral collapse of volcanoes in recent times in the Southwest Pacific islands, three of which have involved loss of life : Ambae, Vanuatu (1913), about 50 deaths, White island, New-Zealand (1914) 11 fatalities, and Ritter island (Papua-New Guinea (1888) when a major cone collapse without signs of volcanic eruptions led to the formation of a tsunami 12-15 m high on nearby islands and several hundred people were probably killed. (Cook, 1981). During the same year, debris avalanche occured on the Bandai volcano (Japan) and killed about 116 people.

Volcanic tsunami are fortunatly rare phenomena but history neverthless some notable disasters for islands. The collapse of the greater part of Santorini volcano, (1400 BC) is believed to have generated a huge tsunami which devastated the coast of Crete and the Agean islands. The tsunami at Krakatau volcano in 1883, which killed 36.000 people on the bearby coast of Java and Sumatra have been

attribued to the submarine colapse of the caldera floor, but may also have been caused by the entry of large pyroclastics flows into the sea.
Many oceanic island volcanoes display clear evidence for edifice failure. Many flank failures have generated tsunami (Keating & McGuire, 2000). Surprisingly, recent events showed that small landslides can also produce local tsunami
Recently in 1982, eruption of Mount Colo on Una Una island (Indonesia) produced a small tsunami which destroyed nearby coastal settlements. On 30 December 2002 a flank collapse occured on the Stromboli volcano (Italy). Two separate rock bodies detached from the Sciara del Fuoco at 7 mn distance, causing two tsunami waves that destroyed the eastern coast of the island up to 10 m elevation et severely damaged several building. Luckily, no people were killed during this event (Calvari and al., 2002)
Others tsunamis are caused by faulting on the flanks of volcanoes, pyroclastics flows from subaerial part of the volcano island that travel over water (Krakatau, 1883 ; Soufriere St.Vincent 1902), and by shock waves generated by subaerial volcanic explosion. Eruption at Myojin Reef (Bayonnaise Rocks) in Japan generate tsunami by shockwave and by collapse of explosion-generated water columns (Niino, 1953) Latter (1981) also gives underwater explosion as the cause of small tsunamis at Anak Krakatau (Sthen, 1929), Myojin Reef (Niino, 1953) and Tuluman (Reynolds and Best, 1976). Collapse of pyroclastic flows into water has produced the largest and diedliest of these tsunamis.

Volcano name	Year	Inferred causes	effects
Okinawa-Tori Shima (Jap)	1664	Submarine explosion (?)	Damage, fatalities
Sakurajima (Jap)	1781	Submarine explosion	Damage, fatalities
Mauna Loa (Hawaii)	1868	Eruption, earthquake	Damage, fatalities
Krakatau (Indonesia)	1883	Pyroclastic flows	Damage, Fatalities
Augustine (Alaska)	1883-84	Pyroclastic flows	Damage
Ritter Island (PNG)	1888	Flank collapse	Damage, fatalities
Soufriere St.Vincent	1902	Pyroclastic flows	Damage, fatalities
Montagne Pelée	1902	Pyroclastic flows	Damage, fatalities
Bayonnaise Rocks (Jap)	1915	Explosion	?
Paluweh (Indonesia)	1928	Explosion, landslide	Damage, fatalities
Krakatau (Indonesia)	1929	Pyroclastic flows	Damage
Severgin –Harimkotan (Russia)	1933	Pyroclastics flows	Damage, fatalities
Kavachi (Solomon)	1951	Submarine explosion	-
Bayonnaise Rocks (Jap)	1952	Explosion, shock waves	Fatalities
Tuluman (PNG)	1953	Explosion	-
Necker (Hawaii)	1955	Submarine explosion	-
Tinakula (Santa Cruz)	1971	Explosion	Damage
Ritter Island (PNG)	1972-74	Submarine explosion	-
Illiwerung (PNG)	1979,	Landslide	Damage, fatalities
Colo (Indonesia)	1982	Pyroclastic flows	Damage
Illiwerung (Indonesia)	1983	Submarine eruption	Damage, fatalities

Tableau 2 - Main historic tsunamis generated from volcano islands activity (direct or indirect causes) – Sources Smithsonian Institution – H.Gaudru- SVE 2004

To mitigate effects of the volcanic collapse and tsunami in the future, studies and programme should be undertaken :

a) a list of submarine and island volcanoes should be compiled ; This should include details on the potential for collapse and the possible volumes of collapsed material that may be involved.
b) Mapping of surface deposits and geomorphology would be useful in identying past tsunami deposits.
c) Education of at risk population throughout the world so that they can react quickly to warning of possible tsunami, including those of both cone collapse.

Lahars hazards

Mudflows or lahars are very common for any volcanoes. Volcanic lahar may be produced either during eruption (primary lahars) or following eruptions by mobilization of erupted material (rain, melting of snow. or rim failure of crater lakes. Lahars from crater-lake eruption are frequently still hazardous some tens of kilometers dowstream from the summit crater. The flanks of the volcano islands are generally steep and contain loose debris, providing favorable condition for lahar generation. Mudflows are particularly common at volcanoes in the humids tropics. Due to limited area on a volcanic island, hazard from lahars are increasing and large damage and fatalities can be very important.

Volcano name	Year	Causes of lahars	Effects
Furnas (Azores)	1630	Eruptions	Damage, fatalities
Awu (Indonesia)	1701	Eruption	Damage, fatalities
Makian (Indonesia)	1760	Eruption	Damage, fatalities
Awu (Indonesia)	1856	Eruption	Damage, fatalities
Aoba (Vanuatu)	1870	Water ejection, later rainfall	Damage, Fatalities (?)
Awu (Indonesia)	1892	Eruption	Damage, fatalities
Mt.Pelée (Martinique)	1902	Crater lake, phreatic eruption	Damage, fatalities

Tableau. 3 - Main historic destructive and deadly lahars occured in the volcanic islands

In most volcanic islands prone to mudflows, the experience of previous disasters and the mean to reduce their impact in the future are rarely handed down from one generation to the other, because survivors, if any, are few, or because they move to safer areas and are no longer there to share their experience with others. Furthermore, the pressure of fast-growing populations in the island and the search for new dwelling sites can lead to the resettlement of potential hazard areas. In attempting to estimate the possible frequency and nature of future mudflows, it is very useful first to gather such evidence as may be available about the history of mudflows in the island areas. To avoid, or at least allevitate damage from mudflows at a given location, is to assess the hazards involved as realistically as possible. Of course, any such assessment can at best only approximate, in view of the considerable variation in the types and magnitudes of eventual triggering events (e.g. rainfall, earquakes, volcanic activity, etc…)

Conclusions :

In addition to a reliable volcano alert systems, risk arising from volcanic eruption on an island can be substantially reduced by means of limiting the development in hazardous areas. In that sense, volcanic hazard mapping provides the basis for land use regulation, as well as critical information for developing effective evacuation plans. Volcanic islands are very vulnerable areas that require the development of specific emergency-management plans. These plans must a) identify the responsabilities and role of all emergency-management local agencies, (b) allow for training and (c) be exercised regularly in order to test their effectiveness.
Provided that there is a need to reduce hazard and vulnerability we have to consolidate and disseminate existing knowlegde concerning general vulnerability and best practices in disaster management in volcanic islands (reduction, mitigation, preparedness and response) through international cooperation.
Many volcano islands have vulnerable population, needs is to conduct a systematic program for volcano islands to assess the risk of future activity and its effects, including reviews of the know geological data for each volcanic system, detailed geologic survey (where necessary) and volcanic hazard and risk assesment including maps of each inhabited volcano island.
To overcome the vulnerabilty of least developed islands countries and small economies a crucial ingredient in building up a constructive international partnership strategy on natural disaster in volcanic islands should be the implementation of a long-term integrated disaster management plan.

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