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# Influence of volcanic activity on the quality of water collected in roof water catchment systems at Stromboli Island (Italy)

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ABSTRACT

With the aim of detailing the interaction between volcanic emissions and water harvesting by Roof Water Catchment Systems (RWCSs), the present work illustrates the results of a study carried out at Stromboli Island, a small but densely populated active volcanic area in the South of Italy. Concentrations of major and trace elements determined in RWCS waters and sediments revealed clear clues of a contamination with gases and suspended particles of volcanic origin, even if the values of those contaminants considered by the World Health Organization as dangerous for human health are always below the Maximum Admitted Concentration (MAC). In particular, cistern water showed a composition similar to local coastal rainwater, with dissolved ions related not only to sea aerosol but also to volcanic gases and ash leaching, with a secondary enrichment in Ca ions due to the interaction with the limewashed surfaces of both roofs and cistern walls. The simulation of the potential increase in dissolved chemical species due to volcanic ash deposition on the water catchment surfaces indicates the possible exceedance of the MAC for several species. The symptoms of fluorosis affecting elderly people who were young at the time of the 1930–40 volcanic crisis is a clue of a possible volcanogenic fluorine contamination. On the other way, the simulation of the digestion process on solid volcanogenic particulate ingested with drinking water highlighted a potential dramatic increase (orders of magnitudes) of dangerous element concentrations in stomach fluids above their MACs. Despite the evidence of potential health risks induced by volcanic activity, no anamnesic evidence of related pathologies has been found among Stromboli population. This apparent discrepancy is solved taking into account the positive feedback among the good practice in maintaining clean conditions in the harvested waters and the prevalent fallout of volcanogenic ashes away from the main inhabited areas, favoured by the morphological setting of the island and its wind regime.



## 1. Introduction

Roof Water Catchment Systems (RWCSs) are primitive but very efficient water collection systems for domestic uses, still widely adopted worldwide especially in remote and isolated locations deprived of alternative natural sources and not served by waterworks. Like other untreated water collection methods, the use of RWCSs may lead to serious human health problems if natural and/or anthropogenic pollution sources such as faeces of birds, small mammals and reptiles, decay of accumulated organic debris, atmospheric deposition of inorganic and organic chemical compounds, etc., contaminate rain and/or water during its collection and storage (Ahmed et al., 2012a,b). The toxicity of harvested rainwater could derive from different parts of the catchment system, i.e. roof-catchment surface, pipes, cistern materials and their coverage (Gumbs and Dierberg, 1985).

Organic pollutants as polycyclic aromatic hydrocarbons, organochloride pesticides and volatile organic compounds may affect water quality of RWCSs close to inhabited areas, whereas in remote locations with low vehicular traffic and no industrial activities, like small islands, their concentration are generally very low or absent (Sazakli et al., 2007).

Inorganic pollutants, dispersed in the atmosphere as gases and/or solid particulate both of natural and anthropogenic origins, could contaminate water at each stage of the harvesting process, from the formation and precipitation of rain droplets to the accumulation of water reserves into cisterns. In the related scientific literature, attention has been focused especially on the concentrations of heavy metals, since these cannot be chemically transformed or destroyed. As reported by Davis et al. (2001, and references therein) in urban areas heavy metal concentrations generally follow the order $Zn > Cu \approx Pb > Cd$.

Water harvesting by RWCS is of great importance in active volcanic areas because due to their geological nature (high permeability of outcropping rocks) they are often both affected by surface water scarcity, especially in arid or semi-arid climates, and contamination of

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groundwaters due to the interaction with volcanogenic fluids. RWCS waters can be also affected by volcanic activity for several reasons: continuous emissions over long time periods, wide spatial influence and huge mass flow of contaminants (Calabrese et al., 2011), linked to gas emissions and fallout of solid particles and micro particles (Aiuppa et al., 2006). Stewart et al. (2006, and references therein) published a comprehensive review on the impacts of volcanic ash on water supply systems, suggesting that the main problems are due to high levels of acidity, turbidity and fluorine contents. At the same time they highlighted the lack of attention on other soluble elements related to volcanic ash deposition. They presented a study on the effects of Ruapehu (New Zealand) ash deposition from the 1995/96 eruptions, suggesting that the main effects on RWCS water were acidification and high contents of Al, Fe and Mn. Moreover, they pointed out that the elements soluble in volcanic ash leachates should remain soluble in water stored in cisterns. Furthermore, if the flow of volcanic pollutants is very huge and continuous, contamination of drinking water may not be limited to RWCSs in the immediate surroundings of a volcano but can affect wider areas. A peculiar case of a wide scale contamination of a hydrogeological system was reported by Pellegriti et al. (2009) for the Mount Etna area (Italy), where they found an anomalous high incidence of papillary thyroid cancer that could be associated to high concentrations of volcanogenic B, Fe, Mn and V in drinking water resources. Volcanic-related acidity of rainwater can also be an indirect source of contaminants through leaching of elements from the roofing materials into the RWCSs as reported for the Hawaiian volcanoes (Sutton et al., 1997).

With the aim of detailing the interaction between volcanic activity and water harvesting by RWCS, the present work illustrates the results of a study carried out at Stromboli Island, a small but densely populated active volcanic area in the South of Italy. The location of the island, far away from any other potential source of contaminants, makes it an ideal place to evaluate the net effect of volcanic emissions on RWCSs. Concentrations of major and trace elements in rainwater, collected for domestic use in roof catchment systems, have been determined in order to evaluate the interaction of water with gases and suspended particles of volcanic origin in an area extremely influenced by persistent volcanic activity. Additional attention has been focused on the constructive style and use of the RWCS and their role in modifying the quality of collected water, to evidence potential human health issues arising from the continuous use of this resource as drinking water.

## 2. Study area setting

Stromboli Island (Fig. 1) is the northernmost of the Aeolian Islands, a volcanic archipelago located off the northern coast of Sicily (Southern Italy). The island has a total surface area of 12.6 km$^2$ and is characterised by two inhabited areas: the first one, called Ginostra, is the smallest of the two and is located in the western sector; the second one, known as Stromboli, is the main centre and lies in the north-eastern side. Both the villages are located in close proximity (2–3 km) to the top craters with a year-round population of 550 people, which can increase to 5000 during the summer tourist season.

Climate is typical of the Mediterranean area, with the alternation of a warm dry period (spring–summer), with monthly mean temperature up to 25 °C and a minimum of 9 mm of average rain in July, and a mild rainy fall–winter with mean temperature of 11.8 °C in January and precipitation up to 94 mm in December; the previous hydrological data are referred to thirty years monthly averages published by Regione Siciliana (1998). Dominant winds are from the North-West with a secondary preferential direction from South-East mainly in summer (Fig. 1).

Stromboli is characterised by persistent volcanic activity that takes place from several vents located within a crater terrace at 750 m a.s.l. The activity ranges from ash-dominated explosions, one

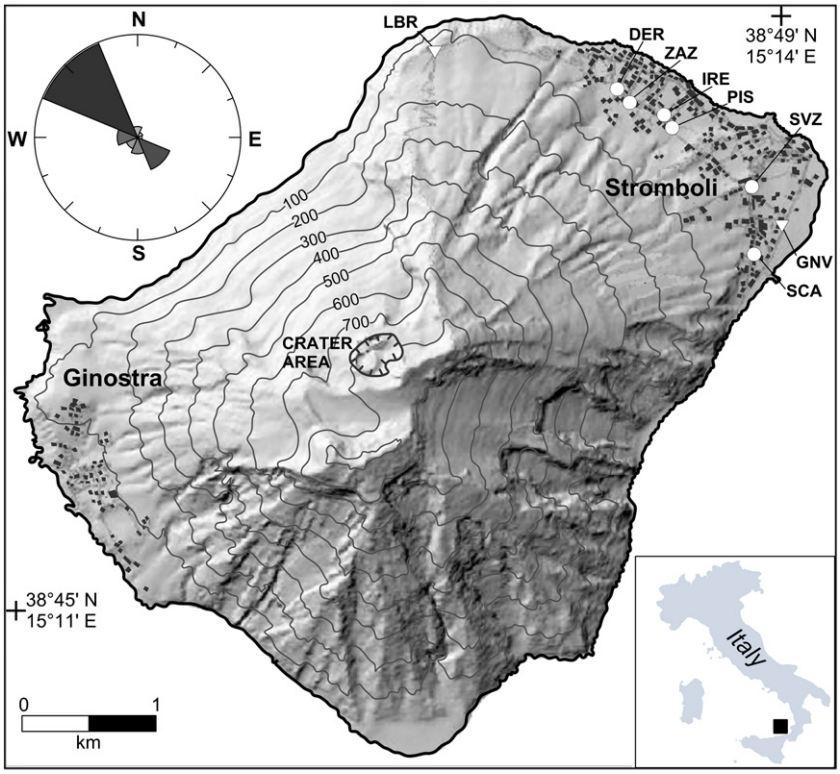


**Fig. 1.** Map of Stromboli Island with locations of the inhabited area, sampled RWCS waters (white circles) and, in the polar plot at the upper left, relative frequencies of dominant wind provenances. The position of rainwater collectors of Bellomo et al. (2003) and Liotta et al. (2006) is also shown.