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Domino effects induced from rockfalls on industrial plants, Brescia, Italy

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The impact of industrial accidents triggered by landslides in the Lombardy Alps (northern Italy) is not negligible, as demonstrated by the event of the refinery Ilsea (Valmadrera, LC), where an explosion caused by a rockfall caused a victim and two injuries in 1981.
This work proposes a methodology for the assessment of societal and economic risk connected to industrial accidents triggered by rockfalls in the area of Brescia, northern Italy. The study area is located between Lake Iseo and Lake Garda, and includes lower Valcamonica, lower Valtrompia, and lower Valsabbia. The area has an extension of 1,508 km2 and includes 82 municipalities. 727,000 people live in this area, where valley bottoms are strongly urbanised, and densely populated.
The expected frequency of occurrence of rockfalls in the area was calculated by combining the frequency of block detachment and the frequency of transit.
The detachment frequency was estimated using intensity-frequency curves, obtained adapting and calibrating existing curves from the literature using historical events of the area (374 events in 20 years). Considering that detachment frequency depends on the size of the block, 7 different scenarios were analysed, each of them characterised by blocks with different volume, from 0.01 m3 to 10,000 m3.
The transit frequency was calculated by means of the rockfall 3D model HY-STONE. The model simulates the propagation of three-dimensional trajectories of blocks on complex terrain morphologies described by a DTM. Simulations were performed using a 20 m x 20 m DTM, and considering as source areas all the cells steepest than 40° (323 km2). Ten blocks were launched from each source, with a stochastic approach that accounts for uncertainties about the modelling parameters. Energy restitution and rolling friction coefficients were assigned to different cells according to different lithology and land use, and calibrated using historical events. As a result of the model, kinetic energy of blocks impacting each industrial plant is obtained. The triggering of an accident caused by rockfall is assumed to occur when the modelled kinetic energy exceeds a critical threshold value.
For each plant, the accident scenarios were defined based on existing External Emergency Plans. Both scenarios for fire and flash fire have been considered.
The analysis shows the societal and economic risks due to domino effects of rockfalls on industrial plants are not negligible.