

## ***Interactive comment on “Experimental assessment of the relationship between rainfall intensity and sinkholes caused by damaged sewer pipes” by Tae-Young Kwak et al.***

**Tae-Young Kwak et al.**

goldenrain91@gmail.com

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An experimental study about the relationships between rainfall intensity and development of sinkholes caused by damaged sewer pipes in Korea is described in the paper. The topic is certainly of interest to NHESS, and the work contains interesting data and considerations. I have listed in the accompanying file a number of small corrections, and a few requests of clarification on some issues that are not clear to me.

Answer: First we are very grateful for your thorough and helpful review. Based on your concerns and comments, we believe that our manuscript has been improved. Please check our answers corresponding to your concerns.

I discourage throughout the manuscript the use of the term “ground cave-ins”, since this is not used in the international literature, and may induce confusion and misunderstandings in the readers.

Answer: Based on your comment, the authors changed the term “ground cave-in” to “sinkhole.”

How were the different rainfall intensity chosen? It is briefly said in the initial part of the paper that this was based upon the rainfall values in South Korea, but then no rainfall data was provided to justify the choice of the adopted values. It would be good to add a few lines, or a figure, to describe the rainfall trend in the area. Further, a brief text explaining the importance of establishing relationships between rainfall and geological hazards could be useful, also referring to other hazards such as landslides (see for instance the works by Peruccacci et al. (2012), Rossi et al. (2012), and Vessia et al.(2012)).

Answer: Currently, the standard for a heavy rain watch in South Korea is 60 mm/3 h (in the case of intense heavy rain) or 110 mm/12 h (in the case of continuous heavy rain), and the standard for a heavy rain warning is 90 mm/3 h (in the case of intense heavy rain) or 110 mm/6 h (in the case of continuous heavy rain). Because the focus of this study was the formation of anthropogenic sinkholes in the event of intense heavy rainfall, the hourly rainfall intensity distributions corresponding to 60 mm/3 h and 90 mm/3 h (which are the criteria for a heavy rain watch and heavy rain warning) were confirmed using data from the Environmental Prediction Research Institute (2017) (as of 2012–2016). In the 60 mm/3 h (based on heavy rain watch) and 90 mm/3 h (based on heavy rain warning) cases, the hourly rainfall intensity distributions corresponding to 30–50 mm/h and 40–60 mm/h were the highest, respectively. In the heavy rain watch case, the rainfall intensity distribution of 30–50 mm/h was 72.9 %, and in the heavy rain warning case, the rainfall intensity distribution of 40–60 mm/h was 64.9 %. Therefore, 40 mm/h and 50 mm/h were applied in this study by using the average value for the section with the highest rainfall distribution for 1 h in terms of heavy rain

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watch and heavy rain warning. In addition, following your comment, we added a brief description of the importance of establishing the relationships between rainfall and geological hazards with suggested references.

When quoting figures throughout the manuscript, please avoid the use of multiple brackets.

Answer: Based on your comment, the authors removed all of the multiple brackets in manuscript.

In general, the reference list can be improved, especially by adding the main international works about sinkhole classification, which are lacking in the present version of the manuscript. Apart from some references directly suggested in the accompanying file, I am enclosing to this comment a list of possible additional references that might be useful to the Authors to improve their paper.

Answer: Based on your comment, the authors included the main international works about sinkhole classification (as recommended by reviewer) in the manuscript.

When quoting more than one paper in the text, the references must be listed in chronological order. This guideline is not followed in the manuscript. Please correct it throughout the text.

Answer: Based on your comment, the authors rearranged the references according to chronological order.

Suggested references: Beck, B.: Soil Piping and Sinkhole Failures. In: Encyclopedia of Caves (Second Edition), White, W. B. and Culver, D. C. (Eds.), Academic Press, Amsterdam, 2012. Closson D, Abou Karaki N (2009) Human-induced geological hazards along the Dead Sea coast. Environ Geol 58:371–380. Gutiérrez, F., Guerrero, J., Lucha, P., 2008. A genetic classification of sinkholes illustrated from evaporite paleokarst exposures in Spain. Environ. Geol. 53, 993–1006. Gutierrez F., Parise M., De Waele J. & Jourde H., 2014, A review on natural and human-induced

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geohazards and impacts in karst. *Earth Science Reviews*, vol. 138, p. 61-88, doi: 10.1016/j.earscirev.2014.08.002. Parise M., 2015, A procedure for evaluating the susceptibility to natural and anthropogenic sinkholes. *Georisk*, vol. 9 (4), p. 272-285, DOI:10.1080/17499518.2015.1045002. Parise M., 2019, Sinkholes. In: White W.B., Culver D.C. & Pipan T. (Eds.), *Encyclopedia of Caves*. Academic Press, Elsevier, 3rd edition, ISBN 978-0-12-814124-3, p. 934-942. Parise M., Pisano L. & Vennari C., 2018, Sinkhole clusters after heavy rainstorms. *Journal of Cave and Karst Studies*, vol. 80 (1), p. 28-38. DOI: 10.4311/2017ES0105. Peruccacci, S., Brunetti, M. T., Luciani, S., Vennari, C., and Guzzetti, F.: Lithological and seasonal control on rainfall thresholds for the possible initiation of landslides in central Italy, *Geomorphology*, 139–140, 79–90, 2012. Rossi, M., Peruccacci, S., Brunetti, M. T., Marchesini, I., Luciani, S., Ardizzone, F., Balducci, V., Bianchi, C., Cardinali, M., Fiorucci, F., Mondini, A. C., Reichenbach, P., Salvati, P., Santangelo, M., Bartolini, D., Gariano, S. L., Palladino, M., Vessia, G., Viero, A., Antronico, L., Borselli, L., Deganutti, A. M., Iovine, G., Luino, F., Parise, M., Polemio, M., and Guzzetti, F.: SANF: a national warning system for rainfall-induced landslides in Italy, in: *Proceedings of the 11th International Conference and 2nd North American symposium on landslides*, Banff, Alberta, Canada, 3–8 June, 2012. Vessia G., Parise M., Brunetti M.T., Peruccacci S., Rossi M., Vennari C. & Guzzetti F., 2014, Automated reconstruction of rainfall events responsible for shallow landslides. *Natural Hazards and Earth System Sciences*, vol. 14, p. 2399- 2408. Waltham, T., Bell, F., Culshaw, M., 2005. *Sinkholes and Subsidence*. Springer, Chichester, (382 pp.). White, W.B., 2002. *Karst hydrology: recent developments and open questions*. *Eng. Geol.* 65, 85–105. For all the considerations above, I recommend minor revision. I believe that, after some corrections, and following the journal guidelines for citations, the manuscript may become acceptable for publication.

Please also note the supplement to this comment:  
<https://nhess.copernicus.org/preprints/nhess-2020-143/nhess-2020-143-RC2-supplement.pdf>

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Answer: The authors considered the comment made by the reviewer in the revision.

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