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Re-assessment Estimation of the Wastewater Treatment Plants' Seismic Vulnerability

KERPELIS, P.[1,2*], GOLFINOPOULOS, S.[1], ALEXAKIS, D.[2]

[1]Department of Financial and Management Engineering, School of Engineering, University of Aegean, 41 Kountourioti Str., GR-82132 Chios, Greece

[2]Laboratory of Geoenvironmental Science and Environmental Quality Assurance, Department of Civil Engineering, School of Engineering, University of West Attica, 250 Thivon & P. Ralli Str.,GR-12241 Athens, Greece

*corresponding author
e-mail: kerpelis@uniwa.gr

Abstract. Many empirical studies use questionnaires for the vulnerability estimation of technical structures. Wastewater Treatment Plants (WWTPs) are critical infrastructure whose the seismic impacts may affect the environment and the society. Interesting results are revealed from the comparison of seismic vulnerability questionnaires granted between different periods.

In this study a Questionnaire "A" (Que-A) of 44 questions was distributed to the responsible operators of a representative sample of 116 Greek WWTPs during 7 months in 2021. After six months, a similar Questionnaire "B" (Que-B) of 14 questions was distributed to another representative sample of responsible operators of 40 WWTPs which lasted 3 months in 2022. Both surveys were used Likert Scale and were checked for their internal reliability and validity.

The results revealed that the recipients were graduated operators of the WWTPs occupying positions of high responsibility for both "A" and "B" Questionnaires, and their experience didn't differ each other. A limit correlation between vulnerability and seismic vulnerability was noticed in Que-B. No difference was observed between the frequencies for seismic vulnerability of Que-A and vulnerability of Que- "B". The same was occurred comparing the seismic vulnerability of both the Questionnaires. The same results for both the Questionnaires were extracted comparing the seismic vulnerability due to structural vulnerability, non-structural vulnerability or operational vulnerability. Finally, the soil-water pollution in the post seismic period (immediate and after 24 hours) presents the same percentages for both the Questionnaires. Concluding, the study supports the claim that these two Questionnaires produce similar results while Que-A has reliability, and can be used for WWTPs' vulnerability estimations.

Keywords: Wastewater Treatment Plants, Questionnaire, Vulnerability, Seismic Vulnerability, Reliability.

1. Introduction

Wastewater Treatment Plants (WWTPs) are critical infrastructure worldwide and seismic impacts can affect many fields of social life, in parallel with the failures of its structure. Also, the soil and water pollution can have many influences to the environment.

The estimation of seismic vulnerability of these structures is carried out through empirical , analytical and experimental methods (Calvi et al., 2006; Kassem et al., 2020). Methods based on the "Expert Judgement" are most popular for a rapid estimation, considering the earthquake is a violent event. Also, "Rapid Visual Screening" is implemented for buildings for potential seismic hazard, in U.S.A. and Greece (EPPO, 2020; FEMA, 2015).

Scientist efforts are focusing to WWTPs, and specially to structural, non structural and operational seismic impacts, using 5-grade Likert Scale Questionnaires, according the "Expert Judgement" methods (Kerpelis et al., 2021b, 2021a; Kerpelis et al., 2021), although many inaccurate seismic data may be distributed via internet sources (Kerpelis P., 2018). Similar studies were recentely applied focusing to climate change (Kirchhoff & Watson, 2019)

2. Methodology

The present study comparee the Que-A and Que-Bgranted between different periods.Greek WWTPs count 256 units, using primary, secondary and tertiary sewage treatment (reference year 2020). The final statistical population was 241 units. The closed-type questions of Que-A used demographics, structural vulnerability, non structural and orerational questions and chronic evolution of soil-water pollution (Kerpelis & Biba, 2021). It was constructed of 44 Likert Scale questions and was distributed to the responsible operators of a representative sample of 116 Greek WWTPs, during 7 months in 2021 (March-November). The representative sample was revealed using the proportional stratified sampling method of four levels (seismic hazard of the area, degree

of sewage treatment, average Equivalent Population - EIP of the settlement(s) served and sensitivity of the wastewater disposal recipient). Random selection of the statistical sample gave the 116 units for Que-A.

The closed-type questions of Que-B (similar to Que-A) used limitted the above questions of Que-A, in addition to questions about the impacts of WWTPs and the requirements of EU's Directive 91/271 (Kerpelis, 2022). It was constructed of 14 Likert Scale questions and was random distributed to the Que-A representative sample of responsible operators. 40 Greek WWTPs sewage operators completed the Que-B, during 3 months in 2022 (June-August). The period between the two surveys was six months. Both the studies were granted via internet and used all protocols about anonymity. The statistical process predicted the checking of the reliability and validity of them (coefficient Spearman-Brown=0.877 and alpha Cronbach=0.924, respectively).

3. Results of the survey

The statistical program SPSS v. 26 was used to compare Que-A and Que-B. Interesting results were observed as the following.

The recipients were graduated operators of the WWTPs occupying positions of high responsibility for both Que-A and Que-B, and their experience didn't differ each other (Fig. 1). 46.6% of the Que-A replies of the recipients were similar to the 57.5% of the Que-B corresponding replies about their experience. These percentages also prove the reliability of the survey (stat. sign. 0.872>0.05).

Que-B asked about their judgement of the vulnerability and the seismic vulnerability of the WWTPs. 72.5% of them judge that vulnerability is 0-40% (in Likert Scale) and 75.0% of them judge the same Likert percentages for the seismic vulnerability (Fig. 2). However, a limit correlation (Spearman=0.687) (Nunnally, 1978) exists between them when focusing to 0-20% and to 20-40% Likert Scale.

The correlation between the averages of extreme categories of 0-20% and 80-100% for vulnerability of Que-A and the seismic vulnerability of Que-B revealed that these doesn't differ each other (sign. 0.811>0.5). Better results are noticed between the correlation of the seismic vulnerability of the two Questionnaires (sign. 0.900). Also, no difference was observed between the frequencies for seismic vulnerability of Que-A (34.5% of the recipients replied 0-20%) and the vulnerability of Que-B (47.5% of them replied 0-20%) (Fig. 3).

The same satisfactory results were observed at the correlation between structural vulnerability, or non structural vulnerability or operational vulnerability, investigating Que-A and Que-B.

Finally, the soil-water pollution in the post seismic period (immediate and after 24 hours) presents the same percentages for both the Questionnaires. In detail, the statistical significance is 0.334>0.05 (for immediate seismic period) and 0.143>0.05 (for 24 hours post-seismic period).

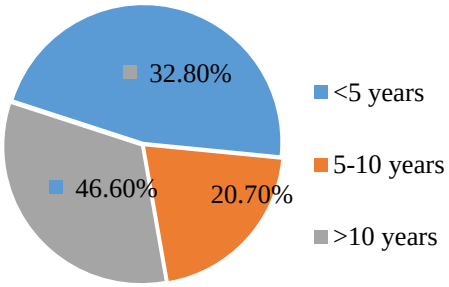
4. Discussion

This survey uses the empirical method of "Experts Judgement" for the estimation of WWTPs' seismic vulnerability.
Excluding of any limitations such as the timing of the carrying out of the survey, any experiences from recent earthquakes etc. the results of a questionnaire can notice seismic vulnerabilities, immediately. The reliability of a questionnaire is proved via a second Questionnaire that can be distributed after a minimum of six months to the same statistical sample to correlate the results.

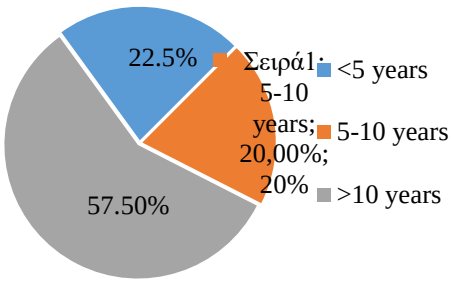
In the present survey, the recipients' judgement showed that reliability exists at their replies. More detailed results can be obtained, after using more detailed Questionnaires. More focused and detailed analytical or/and surveys must complete the seismic vulnerability estimations.

5. Conclusion

The study supports the claim that Que-A and Que-B produce similar results. That means that Que-A has reliability and can be used for WWTPs' seismic vulnerability estimations. The survey proved the empirical method of "Expert Judgement" for Greek Units, investigating a representative sample and calculating with statistical methods. Also, a more rapid estimation can be achieved with Que-B, using fewer questions. The method of reducing the questions can boost productivity, taking care of the parameters introduced. The results for disaster impacts mitigation and safety are obvious. Prevention is obtained to sensitive infrastructure, according to the international Framework for Disaster Risk Reduction of Sendai - UN (2015-30).

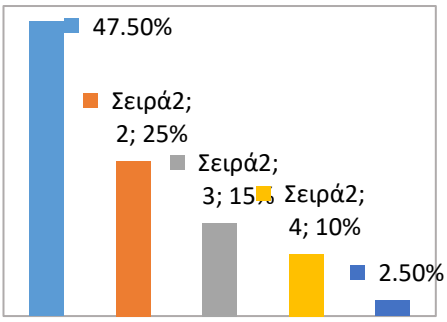


Que-A

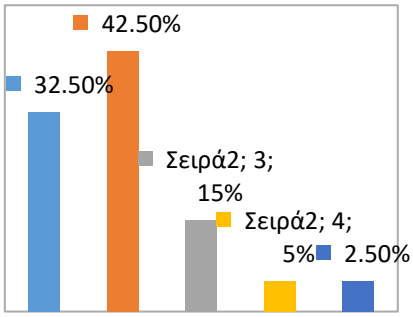


Que-B

Figure 1. Experience of recipients by Que-A and Que-B

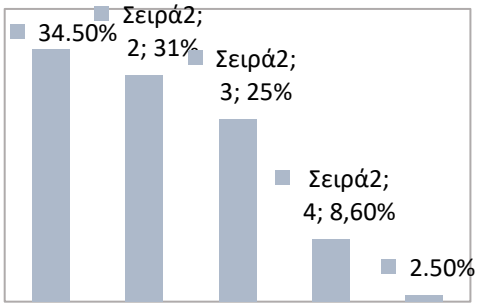


Vulnerability (Que-B)

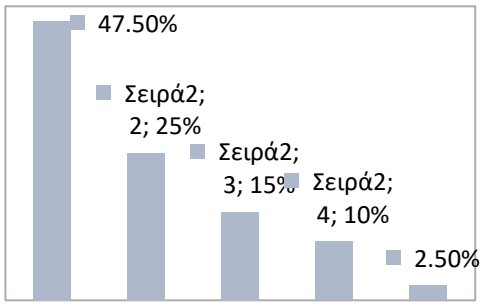


Seismic Vulnerability (Que-B)

Figure 2. Correlation of vulnerability and seismic vulnerability, using Que-B



Seismic Vulnerability (Que-A)



Vulnerability (Que-B)

Figure 3. Correlation of seismic vulnerability (using Que-A) and vulnerability (using Que-B)

References

Calvi, G. M., Pinho, R., Magenes, G., Bommer, J. J., Restrepo-Velez, L. F., & Crowley, H. (2006). Development of Seismic Vulnerability Assessment Methodologies over the past 30 years. *ISET Journal of Earthquake Technology No 472*, *43*(3), 75–104.

EPPO. (2020). *Inspection of Structural Vulnerability*. (In Greek). Available: https://www.oasp.gr/node/76

FEMA. (2015). *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*. Available: www.ATCouncil.org

Kassem, M. M., Nazri, M. F., & Farsangi, N. E. (2020). The seismic vulnerability assessment methodologies: A state-of-the-art review. *Ain Shams Engineering Journal*, *11*(4), 849–864.

Kerpelis, P. (2022). *Re-Assessment Questionnaire for WWTPs*. (In Greek). Available: https://docs.google.com/forms/d/1VZJCYk4Yr0W7AYGxTn3pdwKRx6xmplnCnUDC8t8QxSA/edit

Kerpelis, P., Alexakis, D., Golfinopoulos, S., & Repapis, C. (2021a). Additional Operational Characteristics of the Wastewater Treatment Plants for the Estimation of their Seismic Vulnerability. *6th Distance Education E-*

Learning Summer School on "Wastewater and Biosolids Management" (WWSS21), Poster. Available: https://wastewater2021.eap.gr/wp-content/uploads/2021/08/WWSS21-e-Proceedings.pdf

Kerpelis, P., Alexakis, D., Golfinopoulos, S., & Repapis, C. (2021b). Non-Structural Characteristics of Wastewater Treatment Plants as Factors for Estimating their Seismic Vulnerability. *6th Distance Education E-Learning Summer School on "Wastewater and Biosolids Management" (WWSS21)*, Poster. Available: https://wastewater2021.eap.gr/wp-content/uploads/2021/08/WWSS21-e-Proceedings.pdf

Kerpelis, P., & Biba, E. (2021). *A Seismic Vulnerability Questionnaire for WWTPs*. (In Greek). Available: https://docs.google.com/forms/d/e/1FAIpQLScJHiNzjLVdxhVTYwDDGFRtsSOyp7stVkOoXynSM3MIbGF18Q/viewform

Kerpelis, P. N. (2018). Accuracy of available seismic data in Google Earth. *6th RSCy -International Conference on Remote Sensing and Geoinformation of Environment*. Available: https://doi.org/10.1117/12.2322894

Kerpelis, P. N., Golfinopoulos, S. K., & Alexakis, D. E. (2021). A proposed theoretical approach for the estimation of seismic structural vulnerability of wastewater treatment plants. *Sustainability (Switzerland)*, *13*(9), 4835. Available: https://doi.org/10.3390/su13094835

Kirchhoff, C. J., & Watson, P. L. (2019). Are Wastewater Systems Adapting to Climate Change? *JAWRA Journal of the American Water Resources Association*, *55*(4), 869–880. Available: https://onlinelibrary.wiley.com/doi/abs/10.1111/1752-1688.12748

Nunnally, J. C. (1978). An Overview of Psychological Measurement. *Clinical Diagnosis of Mental Disorders*, 97–146. Available: https://doi.org/10.1007/978-1-4684-2490-4_4