STUDIA UBB CHEMIA, LXI, 3, Tom II, 2016 (p. 365-378)
(RECOMMENDED CITATION)

Dedicated to Professor Emil Cordoș on the occasion of his 80th anniversary

EARLY WARNING SYSTEMS FOR DISASTER RISK REDUCTION: A CASE STUDY IN NORTH-WEST OF ROMANIA

EMIL ROMAN[a], LUCRINA ŞTEFĂNESCU[a], KOZMA KIS ELISABETA-EDITA[a], DAN CHIRIBUCĂ[b], ADRIANA DÎNCU[c], VIOREL ARGHIUŞ[a], ALEXANDRU OZUNU[a,*]

ABSTRACT. Timely and effective warning sets the basis for building the prevention and awareness culture necessary for disaster risk reduction. The paper pursues to assess the awareness level of communities downstream some hydrotechnical facilities in NW Romania in terms of the risks these communities are exposed to and the availability of early warning systems. The research is based on the awareness on early warning systems of a community located downstream of some hydrotechnical facilities on the Somesul Cald River, NW Romania (Central-Eastern Europe), using the social investigation methodology, namely the questionnaire, applied to a group of 516 respondents from the risk-prone area, by the CATI (Computer Assisted Telephone Interviewing) method. The findings reveal the need to increase awareness of population and improve risk communication, as well as to conduct preparedness activities within the local community in order to build their resilience to disasters and improve the knowledge of population on the existing early warning systems.

Keywords: *early warning systems, disaster risk reduction, community awareness, resilience, Romania*

---

[a] *Babeş-Bolyai University, Faculty of Environmental Science and Engineering, Research Institute for Sustainability and Disaster Management based on High Performance Computing, 30 Fantanele str., RO-400294, Cluj-Napoca, Romania str., RO-400028, Cluj-Napoca, Romania*
[b] *Babeş-Bolyai University, Faculty of Sociology and Social Work, 128-130, 21 Decembrie 1989 Blvd. RO-400604 Cluj-Napoca, Romania*
[c] *Romanian Strategy and Evaluation Institute, 150 Turzii Street, Cluj-Napoca, Romania*
* *Corresponding author: alexandru.ozunu@ubbcluj.ro*

INTRODUCTION

Early Warning Systems (EWS) are specially designed monitoring devices and key elements of risk reduction, used to mitigate the effects of natural and technological disasters on humans, property, environment, livelihoods, etc. [1, 2, 3]. Their main goal is to reduce injuries and death toll, economic losses, and social impacts of disasters by providing information that enables people and organizations to prepare for emerging disasters [4] and they are worldwide promoted by international initiatives, along with the development of risk prevention culture [5, 6, 7]. Whereas one of the priorities of the Hyogo Framework was to identify, assess and monitor disaster risks and enhance early warning, the new international framework for disaster risk reduction (DRR) focuses on enhancing multi-hazard early warning systems [8].

As human population represents the most important component of the disaster management cycle, effective EWS need to actively involve the communities at risk, to facilitate public education and awareness, to communicate and disseminate warning messages, and to ensure a constant state of preparedness [9]. EWS are integrated in the preparedness plans to monitor and predict the occurrence of hazards [10]. The disaster preparedness in Romania is currently conducted in a very general manner, so that population has general knowledge of a wide range of natural and technological disasters. Moreover, although information on early warning measures and systems is available, it does not always reach the target groups in need of emergency protection. Public education and awareness on risk scenarios and action models is one of the first steps towards this goal and towards risk prevention and mitigation [11, 12, 13], and should at least include details on the sender of the warning messages, content, timing, and the media used to communicate risk messages [14].

Among the driving factors causing disasters, floods and flash-floods are common phenomena in the temperate-continental climate, affecting human settlements throughout the Romanian territory every year. During the 2000-2009 period alone, the total national flood losses summed up to 4,215 billion US $ [15]. In order to mitigate the negative effects associated with floods and flash-floods, especially during the second half of the 20th century, a series of flood control works were carried. Among these works, most efficient are the reservoirs provided with flood storage capacities. There are currently more than 1,400 reservoirs in Romania, with an estimated volume of 3,700 mil. m^3. Besides their benefits derived from the specific functions (flood control, water supply, fishing, tourism, etc.), the reservoirs imply also negative aspects. Among these, flash-floods caused as a result of dam failures and/or events consisting in sudden high discharges, although very rare, are catastrophic and draw the media's attention, requiring national and even international assistance.

The main objective of this research is to determine the extent to which the communities located downstream of such high-risk facilities are informed on the alarm systems in place and, therefore, prepared to cope with disasters.

EXPERIMENTAL SECTION

The research was conducted in the Somesul Cald River basin (the main course of the Somesul Mic River), also called Somesul Mic River downstream of the confluence with the Somesul Rece River in Gilau. The largest community in the case study area is the city of Cluj-Napoca, the second largest city in Romania, 324,576 inhabitants [16].

The high rainfall amounts in the upper basin, the steep slopes and sparse vegetation in certain areas, all lead to serious floods, causing significant damages and negative impacts on soil due to erosion and excessive humidity. Therefore, flood risk is the specific type of risk along the Somesul Mic River. Several reservoirs were built (Fantanele, Tarnita, Somesul Cald, Gilau I and II, Floresti I and II, and Cluj), but Fantanele and Tarnita are worth mentioning in term of flood control. Their location is represented in Fig. 1 (upper image), together with the longitudinal section diagram (bottom image). However, despite their flood-control function, these facilities induce disaster risks by possible dam failures.

At global level, the dam-related failures and accidents are caused by the loss of stability and sustainability of construction or foundation in the first place (80%), while the operational failures are less frequent causes (14%) [18].

Dam failure can occur due to the singular or factor-related effect of the following elements, and the following are most likely to occur in the study area: exceed of the spillway evacuation capacity; loss of dam stability (landslides, dumping); loss of construction sustainability; foundation instability (in depth landslides, foundation surface landslides, foundation settling, plastic strains, infiltration through foundation or dam, increase of loads, cracking); sudden increase of the water volume in the lake; human error or deliberate actions (e.g. terrorist attacks).

In the case of the Somesul Cald reservoirs, the scenarios considered for the modelling of flash-flood waves resulting from Fantanele dam failure were the following: scenario 1 - full lake and 100 % failure; scenario 2 - 50 %, medium failure.

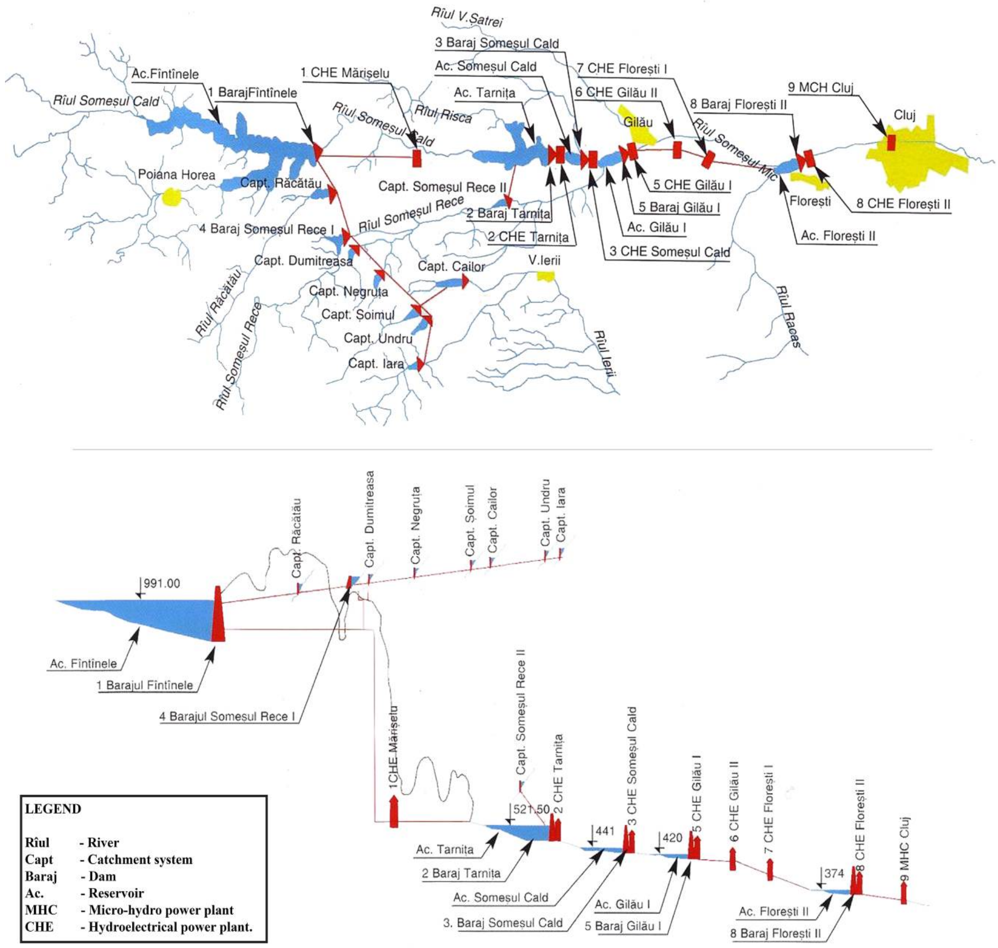

Figure 1. The structure of Somesul Cald (Mic) hydropower facilities system (upper image) and longitudinal section diagram (bottom image) [17]

Considering the worst case scenario of an accident, the 100 % failure of the upstream Fantanele dam, this would lead to the formation of a flash-flood wave in the case study area that would affect approx. 200,000 persons living in the downstream localities. This situation is rather hypothetical, considering that the rockfill dams never fail suddenly or to a 100 % extent. The average velocity of flood propagation to the border of the Cluj-Napoca municipality is estimated to be approximately 60 km/h. The impact with the communities located immediately downstream in the path of the flash-flood occurs within several minutes from the occurrence of the accident. As the city of Cluj-Napoca is located at approximately 47 km, the first impact would occur in approximately 45 minutes [18]. Therefore, one may notice the particular significance of organizing the warning and alerting of population from the areas subjected to risk.

Response plans for the management of hydrotechnical disasters are in place in the Somesul Cald River basin. These plans are drafted based on the modelling of flash-floods resulting after dam failure.

In case of dam failure, the existing warning, alerting and response plans are applied. The Cluj hydropower plant branch will warn all the entities involved in flood emergency management, according to the informational flow block diagram provided by the Romanian Waters National Administration [19].

For the prompt warning of population, alarm systems and devices are timely provided in localities, economic operators and public institutions. The local and central public administration authorities, the heads of public institutions and managers of companies that are considered sources of risk, regardless of their form of ownership, provide special annual budget amounts for the development of civil protection activities, according to Romanian legislation in this field [20, 21, 22, 23]. The number, type and location of alarm devices are determined by the General Inspectorate for Emergency Situations (IGSU), based on audibility analyses.

The alarm should be pertinent, reliable and stable and should ensure the successful warning of population:

- pertinent – ensure the timely warning of population by alarm means and systems that can be activated immediately at the occurrence of aerial attacks or disasters;
- reliable – send the signals intended for warning of population through specific means by the assigned personnel based on the decision of the emergency situation committees presidents;
- stable - warn the population and economic operators under any circumstances.

In order to ensure the warning and alerting of population and to secure the facilities downstream of the dams, a warning and alerting plan and an adequate technical system are implemented. For this warning and alerting system to work in a timely manner, information is necessary regarding the state of hydrotechnical facilities and their behavior over time. These data are provided by the hydrometeorological informational system.

The warning for dam failure in the case study area is conducted by the Cluj hydropower plant branch, according to the existing plans and following the approved information and warning flow chart (Fig. 2).

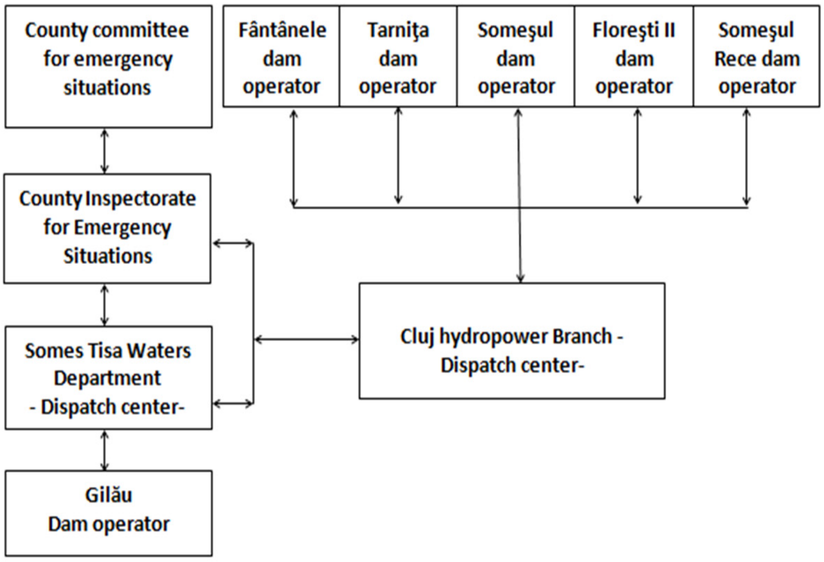

Figure 2. The notification and warning flow chart in the event of dam failure in the case study area

The population, public institutions and economic operators are alerted by acoustic signals emitted by means of the alarm devices and messages sent by the central and local radio and television stations, and, if possible, by rediffusion and radio-amplification.

The acoustic alarm signal for emergency situations “ALARM IN CASE OF DISASTERS” is composed of 5 sounds, 16 seconds each, separated by 10 second pauses. In case of compressed air sirens, the signal is composed of 5 sounds 8 seconds each, separated by 5 second pauses.

The Somesul Cald hydropower plant is equipped with a sound alarm system composed of:

- a warning and alerting system with electronic sirens within the Hydropower Cluj dispatch center composed of a station and 10 electronic sirens located in the flood-prone areas of the dams (Fig. 3);
- centralized alarm systems in the localities downstream of the dams: Gilau, Floresti and Cluj-Napoca;
- mobile systems mounted on vehicles, mobile police crews.

Figure 3. Location of alarm sirens in the case study area (adapted from Google maps)

The information and decision-making system represents an essential element of the emergency situations management and includes the subsystems ensemble designed for observation, detection, measurement, recording, storage and processing of specific data, alarm, information, gathering and communication of information and decisions by all factors involved in the prevention and management of an emergency situation.

The local public administration authorities, as well as the management of the economic operators and institutions located in risk-prone areas have the responsibility to take over from the central and local monitoring stations the necessary meteorological and hydrological data and warnings in order to take preventive and responsive actions.

MATERIALS AND METHODS

The investigation methodology used in the research is CATI – Computer Assisted Telephone Interviewing. In order to assess the information and preparedness level of the population, a public survey was conducted by the use of the CATI method on the population from the Cluj-Napoca, Gilau and Floresti localities. The survey was carried out by the Romanian Strategy and Evaluation Institute (IRES) in February 2013.

The survey was conducted on adult population (+ 18 years) living in the three localities and the sample group was of the simple probabilistic type.

516 respondents were interviewed, distributed approximately to an equal extent between the urban area (Cluj-Napoca – 51% of the cases) and the rural area (Floresti and Gilau – 49% of the cases). The error margin was 4.5%.

The questionnaire was structured into 4 distinct modules. The first introductory module included 2 general, non-targeted assessment indicators of the satisfaction regarding the standard of living and one assessment indicator of the generalized confidence, all with the purpose to define a comprehensive framework for the processing and analysis of the results achieved in the main modules (2 and 3). The 2^{nd} module included a set of indicators regarding the opinions, level of information and expected behavior in emergency situations caused by natural and technological risks. The assessment of the subjective perception of the accident risks addressed a double reference (household and place of residence) and was conducted by means of a Lickert type scale with 7 categories. Value 1 was assigned to the total absence of risk and value 7 was assigned to the certainty or near certainty that the respective risk would occur. Module 3 included a set of indicators regarding the state of health, relevant for the assessment of the social vulnerability in the investigated area. Module 4 included socio-demographic data (gender, age, nationality, marital status, education, type of household, number of persons in the household, incomes, etc.) significant for the identification of the assessed behavior variation (perception of risks, information level, behavior response in emergency situations), depending on various subpopulation categories.

RESULTS AND DISCUSSION

Regarding the population perception of hydrotechnical accident risk, the survey highlighted a rather low level of public concern (Fig. 4). Only 16% of the population considered this risk to be very high (5%) or certain (11%). 41% of the interviewed population stated that the risk was very low (13%) or nonexistent (38%). However, it is worth mentioning that when the intensity of population fear towards a certain type of risk was considered (frequency of responses appreciating a certain type of risk as being very high or high), the investigated population stated that the hydrotechnical accident risk was equally high to that of public utility failure or nuclear accidents and failures. When considering the absence of population's fears (frequency of responses appreciating a certain type of risk as being nonexistent or very low), the hydrotechnical accident was perceived as an event inducing a higher risk of occurrence than industrial accidents (50% of the responses appreciated the respective risk to be nonexistent or very low) and almost equal to the earthquake risk (45% considered this risk to be nonexistent or very low).

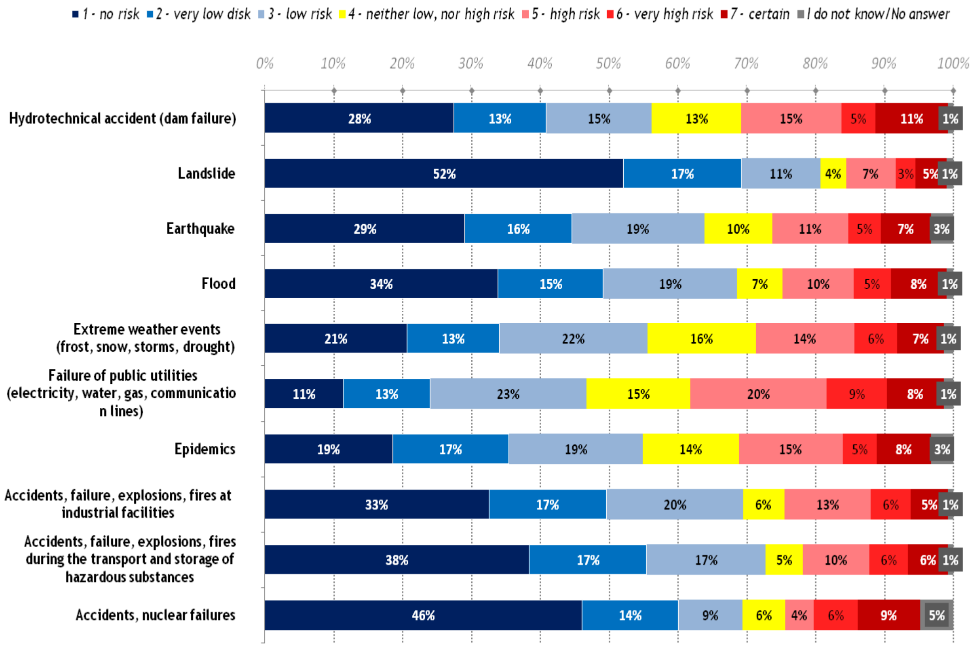

Figure 4. Population opinion regarding certain emergency situations that might damage their households

The assessment of risk perception of a population without any professional knowledge is inherently partial, fragmentary and one-dimensional, considering only the likelihood of a disaster (assessed subjectively and influenced by multiple psychological and socio-cultural variables). Such assessment did not include the gravity of consequences associated with the event occurrence. The public perception of natural or technological disaster risks was also influenced by the previous occurrence of such events. At common sense level and at popular rationale level rather that at logical level, the fact that a disaster never took place in a certain area was a sufficient proof of the very small or nonexistent chances to occur in the future.

The subjective risk perception regarding the occurrence of a disaster should be associated with the interest for the data on such risks. The questionnaire used in the survey did not include sufficient indicators to test such a hypothesis, but the data enabled us to notice the absence of an association relation between the perception of risk and the level of information of the investigated population.

Regarding the extent to which the population was informed on possible disaster risks, the existing warning methods, the knowledge of the signals and response behavior in case of disasters, the data analysis confirmed one of the hypotheses that set the basis of this research: the activities regarding the information of population were insufficient. More than 80 % of the respondents stated that they have received no information on the risks that might cause disasters in their town/village, and neither on the warning and alarm methods and devices used in case of disasters (Fig. 5).

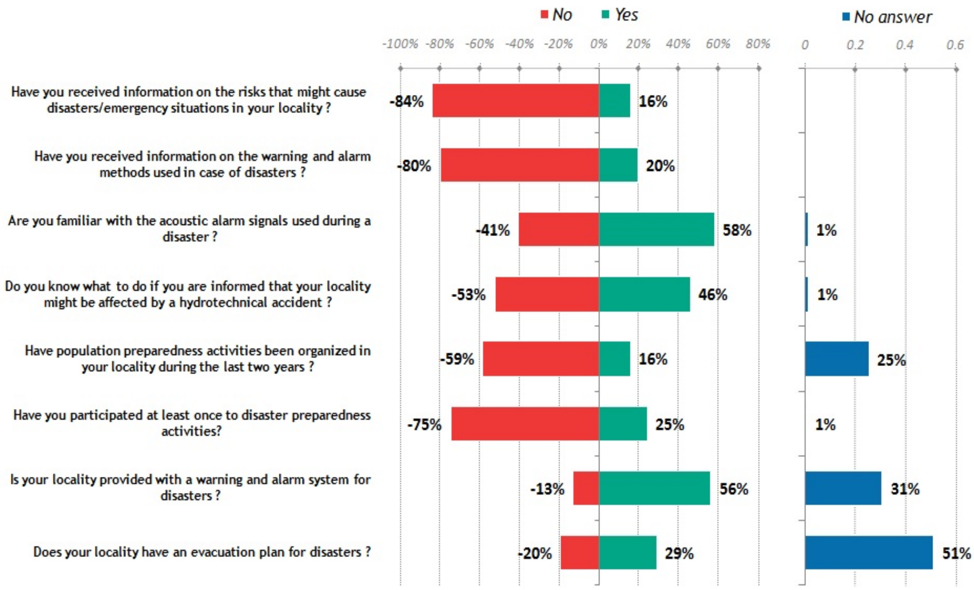

Figure 5. The level of information and preparedness of population for disasters

The main sources of information regarding risks causing disasters and the warning and alarm methods used in the event of disasters were, according to the opinions expressed by the respondents: local mass media, (52%), the city hall (41%), school and Emergency Situation Inspectorates (27 %), the Internet (25%) and NGOs (8%) (Fig. 6).

The data indicated an insufficient use of at least three entities. These had social functions (school), attributes related to the developed activities (Emergency Situations Inspectorates) and a potential to be used as a communication channel in communication campaigns (the Internet), all these enabling and ensuring the improvement of public information.

The low degree of population information was also confirmed by another indicator: despite the fact that almost 60% of the respondents declare that they were familiar with the alarm signals and the existence of a warning and alarm system of population in case of disasters within their localities, only 4% have indicated correctly the acoustic warning signal used to alarm the population in case of disasters.

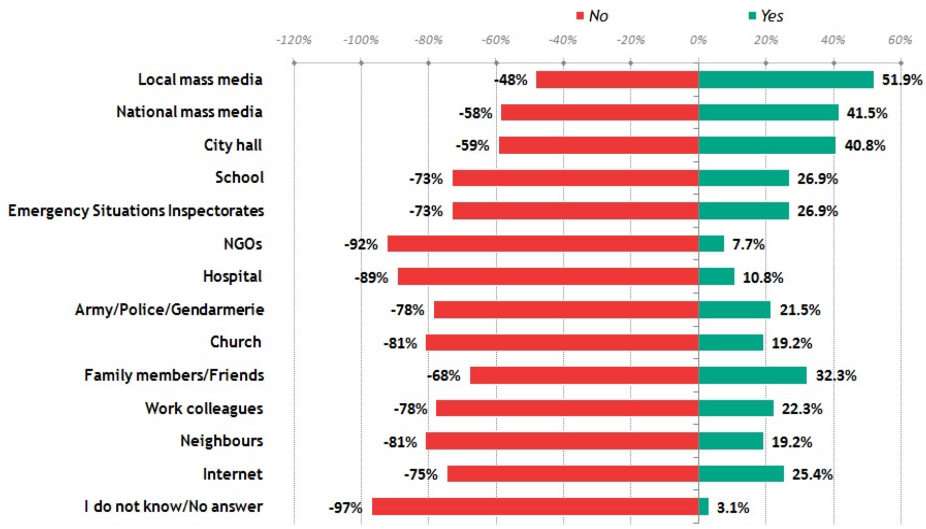

Figure 6. The information sources regarding the risks generating disasters

From the practical point of view, considering also the number of randomly correct answers, the 4% percentage signified that the level of recognizing the acoustic signal by the population was zero, with all the consequences that resulted in the event of a disaster.

The lack of population knowledge of the alarm signals represents, in itself, a powerful “alarm signal” for the public authorities and signifies the need to immediately initiate some public communication campaigns regarding the disaster information and preparedness of population. Moreover, the percentage of the population declaring that they knew what to do in the event of a hydrotechnical accident was less than half of the total investigated population (46%). In terms of the expected behavior in the event of a disaster, almost half of the subjects would choose incorrect actions. A relevant example was given by the high number (23%) of persons who declared that in case of a hydrotechnical accident they would call the emergency number 112 to receive detailed instruction, as this behavior would increase the risk that the emergency communication lines were blocked in a real situation by those waiting for instructions, therefore becoming inoperable or difficult to access for emergency response purposes.

Overall, the data indicated poor knowledge of the national (local) emergency management system, poor communication and engagement of the public institutions, as well as insufficient knowledge regarding the unitary response concept drafted at local level.

The collaboration between the community and the disaster preparedness administrative structures is essential in organizing and implementing a feasible and efficient warning system to reduce the negative effects of disasters and increase community resilience. The current research is not meant to be a comprehensive and unquestionable indicator. However, when asked directly about the quality of collaboration between the community and local authorities in the field of disaster preparedness, 63% of the respondents appreciated that this was completely missing or it was very poor.

CONCLUSIONS

One of the main conclusions resulting from the above data is that, although there is a technical alarm system implemented within the localities downstream of the hydrotechnical facilities in the Somesul Cald Valley, its efficiency is not yet confirmed. However, the nature of the causes for this situation is not technical, but it is related to the public information, communication and preparedness component. A technical system cannot be effective unless doubled by a good management of activities, by a unique concept of implementing a coherent decisional informational system and by dissemination of information to all members of the community. It is necessary that the community members understand the risks, as well as the disaster risk reduction measures, warning methods and modes of action, in order to mitigate the effects and reduce the losses.

The emergency situations management authorities should conduct population awareness building activities regarding the risks they are subjected to, while the communication, information and preparedness efforts should be directed towards these risks.

The degree to which population is informed on the existing risks, as well as the level of preparedness should be enhanced, with the active involvement of the local public authorities, the competent institutions, NGOs, and mass-media. Building communities' awareness on risks in their locality and providing them the necessary information, as well as organizing preparedness activities and encouraging active involvement are all necessary steps to be taken immediately to increase their resilience to disasters.

The revision of school curricula is also necessary, to insert topics regarding the preparedness and protection in the event of disasters, at all levels of education. Considering the special role that children have in disseminating information they learn in schools to their families, the school should provide complete and pertinent information on this topic.

Disaster preparedness is currently conducted at a general level, so that information on a wide range of natural and technological disasters is available to population. Moreover, although information is available, it does not always reach the target groups and those that should be familiar with the disaster reduction measures.

For a better protection of population in the event of hydrotechnical accidents, the implementation of several disaster risk reduction measures is necessary, such as organizing information and building awareness campaigns on types of risks and their manner of occurrence, as well as on the protective measures to be taken in such events. Organizing warning and alerting, evacuation and intervention exercises and practicing the alarm signals and the correct disaster behavior would also lead to increased community resilience to disasters.

Media campaigns on the alarm signals are also needed in the case study area, together with actions to replace the existing acoustic alarm signals with a unique one, doubled by messages sent through media and other communication ways. It is essential to correctly inform the population on the responsibilities of the 112 emergency services and their role in disaster management to increase the efficiency of response operations and, more importantly, not to hinder them.

REFERENCES

1. E. Intrieri, G. Gigli, F. Mugnai, R. Fanti, N. Casagli, *Engineering Geology*, **2012**, *147-148*, 124.
2. J. Birkmann, D.C. Seng, N. Setiadi, *Environmental Science & Policy*, **2012**, *27(1)*, S76.
3. B. Balis, M. Kasztelnik, M. Bubak, T. Bartynski, T. Gubała, P. Nowakowski, J. Broekhuijsen, *Procedia Computer Science*, **2011**, *4*, 96.
4. UNEP, Early Warning Systems: State-of-Art Analysis and Future Directions, Division of Early Warning and Assessment, *United Nations Environment Programme*, Nairobi, Kenya, **2012**, 63.
5. L. Alfieri, P. Salamon, F. Pappenberger, F. Wetterhall, J. Thielen, *Environmental Science & Policy*, **2012**, *21*, 35.
6. P. Gasparini, G. Manfredi, J. Zschau, *Soil Dynamics and Earthquake Engineering*, **2011**, *31*, 267.
7. F. Thomalla, T. Downing, E. Spanger-Siegfried, G. Han, J. Rockström, *Disasters*, **2006**, *30(1)*, 39.
8. UN, Sendai Framework for Disaster Risk Reduction 2015–2030, *United Nations General Assembly*, **2015**.
9. UNISCDR, EWC *Third International Conference on Early Warning, From concept to action*, Bonn, Germany, **2006**.

10. R. Palliyaguru, D. Amaratunga, D. Baldry, *Disasters*, **2014**, *38(1)*, 45.
11. A. Ozunu, F. Senzaconi, C. Botezan, L. Ştefănescu, E. Nour, C. Balcu, *Nat. Hazards Earth Syst. Sci.*, **2011**, *11*, 1319.
12. A. Ozunu, A. Gagiu, C. Costan, E. Nour, *NATO Science for Peace and Security Series - E: Human and Societal Dynamics*, **2011**, *80*, 3.
13. E.E. Kozma Kis, L.T. Deaconu, E. Roman, L. Ştefănescu, M. Meltzer, C. Pop, A. Ozunu, *Advances in Environmental Sciences Bioflux*, **2013**, *5(2)*, 158.
14. G.S. Leonard, D.M. Johnston, D. Paton, A. Christianson, J. Becker, H. Keys, *New Zealand Journal of Volcanology and Geothermal Research*, **2008**, *172*, 199.
15. V. Arghiuş, C. Botezan, A.C. Gagiu, I. Samara, F. Senzaconi, A. Ozunu, *Environmental Engineering and Management Journal*, **2011**, *10(1)*, 17.
16. INS, *National Institute of Statistics*, **2011**.
17. HIDROCONSTRUCTIA, *Development of River Somesul Mic Study*, **2000**, available at: http://www.hidroconstructia.com/dyn/2pub/proiecte_det.php?id=294&pg=48.
18. ISPH, The Warning – Alarm Plan of Population, economic and social objectives located downstream of the reservoirs, in case of accidents in the hidrotechnical facilities in the Somesul Mic river basin 2005-2015, (in Romanian), *S.C. Institutul de Studii şi Proiectări Hidroenergetice S.A.,* ISPH (Hydrothechnical Studies and Design Institute), Bucharest, **2005**.
19. ANAR, Romanian Waters National Administration Official website, http://www.rowater.ro/Continut%20Site/Flux%20informa%C5%A3ional%20pentru%20situa%C5%A3ii%20de%20urgen%C5%A3a.aspx, **2013**.
20. Law 481 of November 8th regarding the civil protection, *Romanian Official Gazette*, No. 1094 of November 24th, **2004**.
21. Emergency Governmental Decision no. 21 of April 15th, regarding the National Management System for Emergency Situations, *Romanian Official Gazette*, Part I, No. 361 of April 26th, **2004**.
22. Emergency Governmental Decision no. 1 regarding some measures in the field of emergency situations management and for the amendment and supplement of EGD 21/2004 regarding the National Management System for Emergency Situations, *Romanian Official Gazette*, Part I, No. 88 of February 4th, **2014**.
23. Ordinance 88 of August 30th, 2001 regarding the setting up, organization and operation of public services for emergency situations, *Romanian Official Gazette*, No. 544 of September the 1st, **2004.**