Justification of ways to improve environmental safety during the liquidation of buildings in the conditions of dense development

Dmitry Mihajlovich Mazurin, and *Marina Evgen'eva* Dement'eva[1]

Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, 129337, Russia

Abstract. The article presents the results of the study of negative factors that accompany the process of building demolition and reduce the environmental safety of urban environment. Based on the system analysis of scientific research, the graph of the impact of negative factors on humans and the environment was compiled. The relevance of the study is justified by the need to ensure environmental safety in the production of demolition works. The purpose of the study was to identify the dependence of the level of negative impact on the characteristics of technological equipment and to improve the system of selecting protective measures, taking into account the requirements of legislation in the field of environmental safety. The result of the research is the developed conceptual model of decision-making on the choice and justification of the method of ensuring environmental safety during the liquidation of buildings in the conditions of dense construction on the basis of reducing the level of influence of negative factors. Practical application of the obtained results is possible in the design of building demolition as an additional justification for selecting the number and type of technological equipment, as well as an addition to the quality control system of works.
Keywords: dismantling, recycling, construction waste, crushing plant, pollution, noise, dust, vibration

1 Introduction

One of the features of modern cities is a large number of buildings constructed in the first period of industrial house-building, from 1957 to 1968. These buildings are characterized by high physical deterioration and functional obsolescence [1-3]. Their repair can ensure compliance with safety measures during further operation, but will not significantly improve the quality of life of residents. Therefore, in order to solve the tasks of fundamentally improving the urban environment, housing renovation and preventing the growth of building accidents, a renovation program was launched in Moscow in 2017. By 2032, the city plans to radically renovate the urban development by building environmentally friendly residential neighborhoods.

[1] Corresponding author: 7dem@mail.ru

In this regard, an integral part of comprehensive safety is environmental safety during works at all stages of the life cycle of the capital construction object. The renovation program involves the demolition of more than five thousand residential buildings in the conditions of the existing dense urban development. It is obvious that the demolition of a building is accompanied by dangerous processes and risks both for the ecology of the demolition area and for the population living, working and vacationing there, as well as for the workers at the demolition site [4]. Therefore, the urgent problem faced by construction contracting organizations is the need for a reasonable choice of the most effective ways to protect people and the surrounding urban environment from a set of negative factors accompanying the process of building demolition.

Environmental safety in construction is determined by the permissible levels of negative factors' impact on humans and the environment, which will not cause significant negative damage. The review of scientific studies of organizational and technological processes of building liquidation and disposal of generated construction waste allowed us to identify the main environmental risks [5-8] and make a graph of connectivity of negative factors affecting humans and the surrounding urban environment (Fig. 1). Among the main factors we can single out dust, noise and vibration.

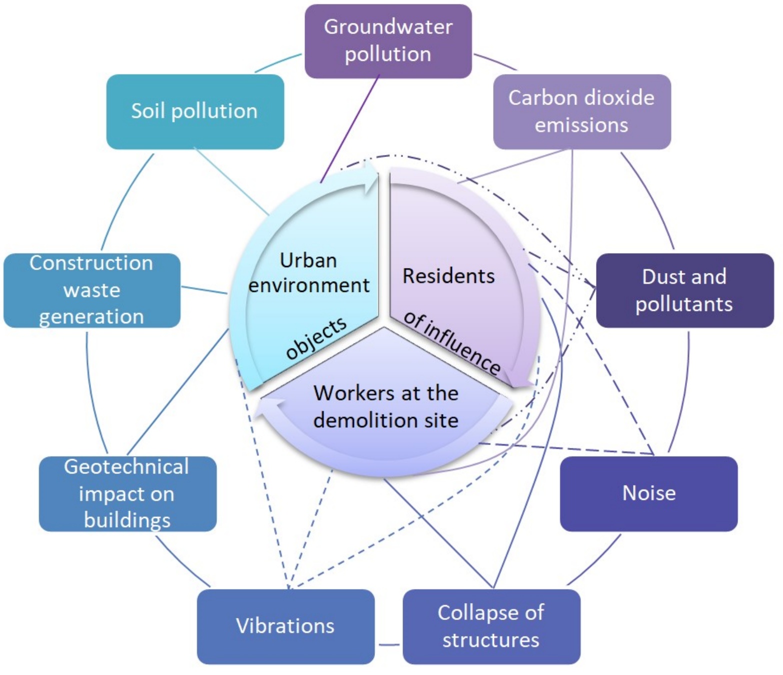

Fig. 1. Graph of the impact of negative factors on human and urban environment during demolition works.

Analysis of the regulatory and technical base in the construction industry shows that air dustiness is characterized by the weight of dust in a unit volume (mg/m^3) or the number of particles in a cubic centimeter. Construction dust is a wide range of fine particles in the air ranging in size from 0.01 to 10 microns [9, 10]. It is generated in large quantities during the dismantling of load-bearing structures and finishing coatings, when building structures fall from heights, during their crushing and loading of construction debris. Thus, when processing reinforced concrete rubble, dust is generated both during primary and secondary crushing, as well as during loading into crushing equipment, and during fractionation of construction waste [11, 12]. Due to the small particle size, construction dust easily penetrates into residential premises even with closed windows and settles on all surfaces in the premises. Dust also has an adverse effect on the health of workers directly on the demolition site. Also, a large amount of dust is generated on construction sites if access roads are not properly maintained [13].

Since March 2021, the construction site must comply with the maximum permissible concentration (MPC) standards for dust according to the latest edition of SanPiN 1.2.3685-21 "Hygienic norms and requirements to ensure safety and (or) harmlessness to humans of habitat factors". In accordance with Table 1.1 of this document, the maximum permissible average daily concentration of dust generated during dismantling and crushing of reinforced concrete structures shall not exceed 0.3 mg/m^3.

Noise in urban environments is another of the most harmful factors that have an unfavorable impact on living conditions and human health. High sound pressure during dismantling works occurs when crushing massive structures with the help of specialized equipment, for example, when operating a hydraulic hammer, as well as when operating mobile crushing plants. The Code of Construction Rules SP 51.13330.2011 "Protection from Noise" establishes maximum permissible sound levels from penetrating noise. Thus, in the period from 7 to 23 hours in residential areas, the values of penetrating noise should not exceed 70 dBA. And the normative noise level during a working shift according to SanPiN 1.2.3685-21 is 80 dBA.

Adverse effects are also caused by industrial vibrations. Their source during dismantling operations is impact, impact-rotational and rotational machines with pneumatic or electric drive. Vibration effects are complex. They lead not only to high muscular loads in workers. In addition, the operation of vibrating equipment is accompanied by noise of high intensity. According to the previously discussed sanitary norms and rules, the maximum permissible level of local vibration in the values of vibration acceleration is 2 m/s^2 or 126 dB. In addition, technological and transportation vibrations can propagate through the building frame and lead to collapse of structures. And ground vibrations can be transmitted to nearby buildings and cause their deformation.

Analysis of a significant number of scientific studies [14-16] allows us to single out some of the most well-known solutions to reduce the negative impact of dust, noise and vibration during demolition of buildings. Thus, the main way to reduce dust formation at the demolition site is water irrigation using pneumatic hoses on demolition equipment, aspiration units and pneumatic guns [17], water-washing machines (Fig. 2). And when transporting construction waste the dump truck is covered with a tent to avoid spreading dustiness in the city.

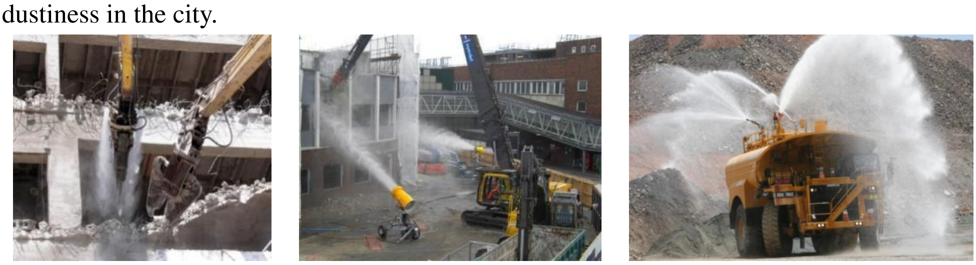

Fig. 2. Examples of water irrigation methods to reduce dust generation during demolition of buildings.

The main way to reduce the noise level at the demolition site is the device of continuous fencing, both the entire territory of the site, and individual sources of noise. Thus, when operating mobile crushing plants at the demolition site, screens (Fig. 3) and enclosures are used. In accordance with SP 51.13330 "Protection from noise" screens are used to reduce sound pressure levels at workplaces in the zone of direct sound and in the intermediate zone. In some cases sound-insulating housings are the only effective means of noise reduction from technological equipment or its separate units. Shrouds allow to significantly reduce noise in the immediate vicinity of operating equipment at the workplaces closest to the source, which cannot be done by other construction and acoustic measures.

Fig. 3. Application of screens for noise protection during operation of crushing plants and dismantling equipment.

The most effective means of protecting a person from vibration is to eliminate direct contact with vibrating equipment. Thus, to protect against noise and vibration when working with a hydraulic hammer, polyurethane-based composites are used as damping elements. The noise level is reduced by more than 10 dBA at a distance of 7.5 m from the noise source. Additionally, for prevention purposes, workers must use personal protective equipment: mittens or gloves, special shoes. It is prohibited to work with vibrating equipment beyond the established working hours. Dismantling work in the area where communications are located, as well as the foundations of nearby buildings, must be carried out with caution, excluding the use of equipment and mechanisms that have a vibration-impact effect on the ground.

The choice of methods of protection from the negative factors under consideration depends on a large number of primary conditions: demolition technology, equipment used, building density, structural and planning solutions of the building, its number of floors, materials of dismantled structures [18-21]. Protection methods must be justified not only by regulatory safety requirements, but also confirmed by technical and economic calculations. Therefore, the research hypothesis is that the choice of protection method will be more effective based on a conceptual model, which is a decision support tool for ranking the priority of protective measures based on mathematical modeling using a criterion-based evaluation mechanism and binary convolution matrices.

2 Materials and Methods

Traditionally, the main conditions for selecting organizational and technological solutions in construction, including in the case of building liquidation, are estimated costs, as well as compliance with legal requirements, including environmental safety requirements. However, a large number of primary conditions complicate the process of selecting effective technologies. For example, when demolishing a building, the most important condition is the selection of the most appropriate equipment.

Therefore, the object of research in this paper was the negative factors arising in the process of building demolition and reducing the environmental safety of the urban environment.

The subject of research was the study of dependence of the level of environmental safety of urban environment on the type of technological equipment used in the process of building demolition and construction waste utilization.

The purpose of the study was to improve the system of selecting protective measures based on the identified dependencies and the requirements of legislation in the field of environmental safety.

To achieve the goal the following tasks were solved:

1. Technical characteristics of equipment for dismantling works were studied and analyzed.
2. Measurements of actual values of negative environmental factors at demolition sites were performed.
3. The system of comparison of technological equipment by indicators of ecological safety was developed.
4. The conceptual model of decision-making on the choice of the optimal method of reducing negative factors during demolition of buildings is offered.

The following assumptions became the basis of the research methodology for solving the set tasks:

- As negative environmentally hazardous factors were taken dust, noise and vibration arising during the production of dismantling works;
- The object of influence of negative factors is a person - a worker at the demolition site;
- Negative factors have one consequence - reduction in the quality of labor conditions;
- The demolition project provides for protective measures, but field tests show their insufficient effectiveness;
- The criteria for assessing the danger of negative factors are the levels of their impact established in regulatory documents, as well as the time of their impact.

In the paper, the following are adopted as decision criteria:

X_1 - severity class of hazardous impact;

X_2 - the degree of influence of the measure on the change in the level of hazard;

X_3 - the degree of influence of the measure on the change in the cost of works.

The degree of non-compliance of the actual values with the normative requirements acts as a criterion for assessing the danger of the negative factor X_1. To establish it, we analyzed the normative requirements for classes of working conditions and their corresponding values of environmental factors. On their basis the system of technological equipment comparison and classification of hazardous impact severity were developed:

1 class of severity - an average level of hazard, at which the actual values do not exceed the maximum permissible ones;

2 class of severity - increased level of danger, at which the actual values exceed the maximum permissible, but do not lead to illness or injury;

3 class of severity - high level of danger, at which actual values are harmful and dangerous, with a high probability leading to illness or injury.

Hazard classes are established on the basis of requirements given in regulatory documents for specific types of negative factors, depending on the level of excess of actually measured values of maximum permissible values (MPC). At 1 class of severity of hazardous impact protective measures are not required. Protective measures are required for severity classes 2 and 3. When selecting them, it is necessary to carry out economic justification, as well as to assess changes in such technological parameters of individual demolition operations as the time of execution and labor costs.

The final conceptual model of decision making (Table 1) on the choice of additional protective measure is based on a point estimate of the level of effectiveness of its implementation [22-24] and takes into account the degree of reduction of the negative impact of the proposed protective measure, the degree of its influence on the increase in material costs during implementation. The following scale of assessment of the degree of influence of an additional measure on the economic efficiency of works is proposed in the work:

1 - additional costs do not exceed 10% of the estimated cost;
2 - additional costs do not exceed 20% of the estimated cost;
3 - additional costs exceed 20% of the estimated cost.

Table 1. Prioritization ranking of protective measures.

Evaluation criterion	**Scale of the effectiveness level of the additional protective measure**		
	I	**II**	**III**
Interpretation of performance level	High	Medium	Low
Severity class before additional intervention X_1	3	2	3
Severity class after the additional measure X_2	1	1	2
Degree of impact of the additional measure on the cost-effectiveness of works X_3	1	2	3

Criteria X_1 and X_2 form the first level matrix M_1 "Environmental Priority of the Action". Matrix M_1 with criterion X_3 forms the matrix of the second level M_2 "Economic priority of the measure".

For the qualitative assessment of the priority of the protective measure when performing the matrix convolution (Fig. 4), the following evaluation values are adopted in the work: "L" - low priority, "M" - medium priority, "H" - high priority.

M_1	X_1		
X_2	3	2	3
1	I	II	I
1	I	II	I
2	II	III	II

M_2	M_1		
X_3	I	II	III
1	H	H	H
2	M	M	L
3	M	L	L

Fig. 4. 1st and 2nd order matrices for prioritizing the selection of a protection measure.

In the course of the study at the demolition sites were measured such parameters as the range of sound power level using a noise meter, dust level using a dust analyzer (dust meter). The level of vibration impact was determined according to the equipment passport data. The duration of noise and vibration impacts was also measured. Processing of the measurement results was performed in accordance with GOST ISO 9612-2016 and GOST R 70230-2022.

3 Results

Dismantling of buildings was carried out by mixed manual and mechanized methods. Dismantling technologies were applied using various excavators with replaceable equipment (hydraulic shears, backhoe, hydraulic hammer), as well as manual dismantling technologies using pneumatic and electrified tools, sledgehammers, and crowbars (Fig. 5).


Fig. 5. Example of photographic documentation of demolition works.

Table 2 presents a comparison of process equipment used in demolition based on in-situ measurements and hazard severity assessments.

Table 2. Example of ranking of technological equipment used in building dismantling and construction waste recycling by the level of hazard of negative impacts.

Name of equipment, tools	Scope of application	Type of impact/ Exposure severity class		
		Dust	Noise	Vibrations
Punching machines and jackhammers	Manual dismantling of load-bearing and non-load-bearing structures	3	3	3
Gas torch	Rebar cutting	1	1	2
Replacement equipment hydraulic hammer	Crushing of massive building structures	3	3	3
Replacement equipment backhoe	Dismantling of buildings, dismantling and loading of construction waste	3	2	2
Replacement equipment hydraulic shears	Primary crushing of reinforced concrete elements	3	2	2
Hydraulic Shears Replacement Equipment	Reinforcement cutting and bundling	3	2	2
Crushing plant	Secondary crushing of reinforced concrete	3	3	3
Vibrating screen	Concrete scrap fractionation	3	3	3

In the course of field measurements it was found that the actual values of negative environmental factors at demolition sites are strongly influenced by the choice of work technology and appropriate technological equipment. The integration of waste utilization directly at the demolition site into the technological process of building dismantling significantly increases the severity of hazardous impacts. Improper organization of work at the demolition site, which may lead to traffic and accumulation of vehicles under the windows of residential buildings, also influence the increase of hazard level. Incorrect planning of work during the working shift may be accompanied by unreasonable sound signals, increasing noise levels during the period when no noisy work should be carried out.

4 Discussion

In the course of the research it was found that the current and most frequently used demolition technologies are characterized by a high level of hazardous impact on people and the environment of such negative factors as dust, noise and vibrations. Therefore, the presence of equipment and construction machinery on the construction site should be justified and confirmed by instrumental measurements and determination of the severity class of negative impacts. In the conditions of the existing dense urban development it becomes an urgent necessity to introduce the stage of protection from sources of danger into the technological process.

Fig. 6 proposes a conceptual model for selecting preferred technologies for protection from hazardous impact factors during demolition of a building. The model is based on the dependence of actual values of negative environmental factors at demolition sites on technological parameters, such as the number and type of equipment, the number of workers in the dismantling of buildings and waste disposal. Integration mechanisms include economic justification of the selected protection methods.

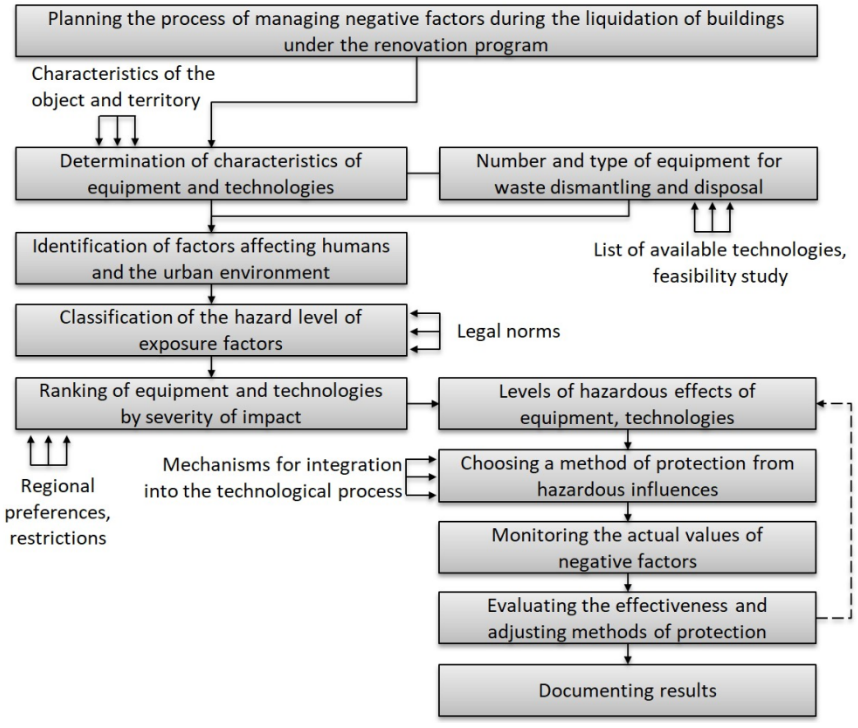

Fig. 6. A conceptual decision-making model for selecting protective measures during demolition to meet the requirements of safety legislation.

5 Conclusions

In the course of the study it was found that the variety of negative factors arising during the liquidation of buildings and utilization of construction waste requires the development of scientifically based approaches to the selection of an effective method of protection against them. The compiled graph of negative factors of influence on people and the environment helps to rank the priority of protective measures.

In the work the system of comparison of technological equipment on indicators of ecological safety on the basis of classification of severity of dangerous influences is offered.

The reliability of the system is substantiated by field measurements and processing of their results according to the methods of state standards.

The scientific significance of the study lies in the fact that the proposed conceptual model is a tool to support decision-making based on mathematical modeling methods, which allows you to choose the option not only with the best technical and economic performance, but also to take into account the requirements of environmental safety.

A flexible system of decision-making criteria is proposed, which allows to make adjustments that take into account the interests of the customer and the performer of works when designing the demolition of a building. The proposed system has practical significance, as it can be included in the system of quality control of design and execution of works on building demolition.

References

1. P. Oleinik, T. Kuzmina, IOP Conf. Ser.: Mater. Sci. Eng. **365**, 062016 (2018) DOI: 10.1088/1757-899X/365/6/062016
2. E. Korol, A. V. Ostyakova, E. Perfilowa, IOP Conf. Ser.: Mater. Sci. Eng. **365**, 062027 (2018) DOI: 10.1088/1757-899X/365/6/062027
3. W. Zheng, Z. Su, W. Zhou, Harbin Gongye Daxue Xuebao **51**, 12, 13-19 (2019) DOI: 10.11918/j.issn.0367-6234.201812053
4. E. Korol, Y. Gaydysheva, D. Passmore, MATEC Web of Conf., **251**, 06031 (2018) https://doi.org/10.1051/matecconf/201825106031
5. S. E. Manzhilevskaya, L. K. Petrenko, A. O. Kilian, E. I. Kocherigin, The Eurasian Sci. J. **2**, 11, 70-78 (2019) https://esj.today/PDF/29SAVN219.pdf
6. A. Seemann, F. Schultmann, O. Rentz, In Design for Deconstruction and Materials Reuse, CIB Publication: Rotterdam, The Netherlands, **272**, 15-26 (2002) https://api.semanticscholar.org/CorpusID:114093318
7. N. K. Sharma, Int. J. Adv. Sci. Technol. **29**, 5343-5350 (2020) http://sersc.org/journals/index.php/IJAST/article/view/22187
8. D. Synitsyn, Adv. Intell. Syst. Comput. **692**, 720-728 (2017) DOI: 10.1007/978-3-319-70987-1_76
9. V. N. Azarov, I. V. Tertishnikov, Ye. A. Kalyuzhina, N. A. Marinin, Vestnik-volggasu **25** (44), 402-406 (2011) https://www.elibrary.ru/item.asp?id=18000293
10. D. E. Ippolitov, Building Expert RIA (2022) https://ardexpert.ru/article/23302
11. P. Oleinik, T. Kuzmina, V. Zenov, V. Melnichuk, MATEC Web of Conf. **251**, 02032 (2018) DOI:10.1051/matecconf/201825102032
12. L. Grigorieva, P. Oleinik, Solid State Phenomena **871**, 126-131 (2016) DOI: 10.4028/www.scientific.net/MSF.871.126
13. D. E. Ippolitov, Yu. V. Popova, State Budgetary Institution "CEIIS" (2019) https://ceiis.mos.ru/presscenter/news/detail/8108781.html
14. L. K. Petrenko, S. E. Manjilevskaya, A. A. Tutaev, E. V. Timoshenko, Ing. J. of Don **1** (52), 167 (2019) ivdon.ru/ru/magazine/archive/n1y2019/5658
15. T. N. Patrusheva, N. G. Vasilovskaya, S. K. Petrov, Int. J. of Appl. and Fundam. Res. **6-1**, 47-50 (2017) https://applied-research.ru/article/view?id=11619
16. G. Suciu, C. Beceanu, A. Scheianu, I. Petre, 20th Int. Multidisc. Sci. GeoConference, Sofia **20**, 237-244 (2020) DOI: 10.5593/sgem2020/4.1/s18.030

17. D. P. Borovkov, E. Yu. Kozlovtseva, M. V. Ivanov, I. V. Tertishnikov, Bull. of Volgograd State Univ. of Arch. and Civil Eng.. Ser.: Civil Eng. and Arch. **1**, 196-205 (2022) https://www.elibrary.ru/item.asp?id=48207441
18. D. Mazurin, , M. Dement'eva, Int. Sci. Siberian Transport Forum TransSiberia-2021, Lecture Notes in Networks and Systems **403**, 1285-1293 (2022) https://doi.org/10.1007/978-3-030-96383-5_143
19. E. Korol, Y. Gaydysheva, IOP Conf. Ser.: Mater. Sci. Eng. **661**, 012141 (2019) DOI: 10.1088/1757-899X/661/1/012141
20. D. M. Mazurin, M. E. Dement'eva, Monthly J. on Constr. and Arch. **16** (6), 741-750 (2021) DOI: 10.22227/1997-0935.2021.6.741-750
21. D. Sinitsyn, MATEC Web of Conf. **170**, 03019 (2018) DOI: 10.1051/matecconf/201817003019
22. M. Dement'eva, I. Terekhin, A. Lebedeva, MATEC Web of Conf. **251**, 06012 (2018) DOI: https://doi.org/10.1051/matecconf/20182510601
23. O. O. Akinade, L. O. Oyedele, M. Bilal, S. O. Ajayi, H. A. Owolabi, H. A. Alaka, S. A. Bello, Resour. Conserv. Recycl. **105**, 167-176 (2015) https://doi.org/10.1016/j.resconrec.2015.10.018.
24. M. Dement'eva, E3S Web of Conf. **371**, 02049 (2023) DOI: https://doi.org/10.1051/e3sconf/202337102049