Procedia
Environmental Science, Engineering and Management
http://www.procedia-esem.eu

Procedia Environmental Science, Engineering and Management 11 (2024) (4) 539-549

27th International Trade Fair of Material and Energy Recovery and Sustainable Development, ECOMONDO, 5th-8th November, 2024, Rimini, Italy

ENHANCING SAFETY IN GREEN JOBS: THE SOHS PROJECT FOR EFFECTIVE SAFETY TRAINING IN WASTE MANAGEMENT PLANTS*

Matteo Gremo[1], Barbara Rita Barricelli[2], Roya Biabani Reshtehroudi[3], Raffaele Cioffi[4], Giuseppe De Palma[5], Daniela Fogli[2], Niccolò Leonardi[6], Margherita Micheletti Cremasco[4], Niccolò Pampuro[6], Emma Sala[7], Mentore Vaccari[3], Federica Caffaro[1]**

[1]Department of Education, University of Roma Tre, Rome, Italy
[2]Department of Information Engineering, University of Brescia, Brescia, Italy
[3]Department of Civil Engineering, Architecture, Territory, Environment and Mathematics, University of Brescia, Brescia, Italy
[4]Department of Life Sciences and Systems Biology, University of Torino, Turin, Italy
[5]Department of Medical and Surgical Specialties, Radiological Sciences and Public Health, University of Brescia, Italy
[6]Institute of Sciences and Technologies for Sustainable Energy and Mobility (STEMS) of the National Research Council (CNR) of Italy, Turin, Italy
[7]Unit of Occupational Medicine, Hygiene, Toxicology and Occupational Prevention, ASST Spedali Civili di Brescia, Brescia, Italy

Abstract

Occupational Safety and Health (OSH) has a remarkable impact on the productivity of companies, as well as on their environmental and social responsibilities. The combination of "safe" and "green" becomes particularly challenging when we consider municipal solid waste management (MSWM). Workers in this sector engage in tasks that promote resources sustainability and the preservation of the planet, but these activities are often "Dirty, Dangerous and Demeaning" and the combined exposure to multiple hazards (chemical, biological, biomechanical and psychosocial) and unpredictable waste materials in plants represents an emerging risk. Safety training is crucial for accident prevention and the evolution of training through the integration of digital technologies becomes essential to improve its effectiveness. The SOHS (Sustainable Occupational Health and Safety) project addresses these challenges through a human-centered ergonomic approach. Four Italian academic partners collaborate to create a prototype of a gamified training solution based on a multidimensional occupational risks

*Selection and peer-review under responsibility of the ECOMONDO
** Corresponding author: e-mail: matteo.gremo@uniroma3.it

assessment in two waste management plants. The multi-method risk assessment relies on both objective and subjective data. The case studies treat different materials (plastic, paper and cardboard), process similar quantities of materials and are similar in the level of mechanization of their activity. The first phase of the risk assessment included the administration of a questionnaire to 31 workers and observation of working postures of 12 workers from the two plants. The results pointed out specific needs in the two plants for workstation re-design to improve workers' posture and workload, based on their anthropometric and behavioral variability. Participants declared to be familiar with digital devices but their potential as safety training tools has to be further explored. Objective and subjective data will be integrated and used to create game scenarios with rewards and penalties in the prototype of the innovative training tool with potential for industry-wide adoption in the waste management sector.

Keywords: digital innovation, gamified training, occupational safety, waste management

1. Introduction

The rate of waste generation is greatly increasing and it represents a big issue all over the world (Kaza et al., 2018). The world generates 2.01 billion tons of municipal solid waste annually and this is expected to increase further, reaching 3.40 billion tons per year by 2050, unless we take significant and effective action (ibidem). Recycling waste is synonymous with sustainability to create a more balanced world system, which is in line with the Circular Economy principle. As a result, the Municipal Solid Waste Management (MSWM) industry is rapidly expanding with an increase in waste sorting and recovery facilities as well as waste management workforce (Song et al., 2022; Szulc et al., 2022). This industry is linked to sustainability, environmentally sound management and resource efficiency (Gregson et al., 2016).

However, MSWM workers often do not operate under sustainable conditions. Working in the resource recovery industry involves tasks such as separating, sorting and segregating discarded materials or waste (Gregson et al., 2016), which can be Dirty, Dangerous and Demeaning (DDD). The job is often monotonous and physically demanding and this sector is highly hazardous due to the combination of chemical, biological, biomechanical and psychosocial factors (EU-OSHA, 2009). In addition, new risks may emerge when handling unpredictable waste materials, asking for much empirical evidence on the Occupational Safety and Health (OSH) issues to which workers are exposed (EU-OSHA, 2019). In Italy, in 2018, 151 thousand people worked in the MSWM (INAIL, 2021) and of these, from 2014 to 2018, 36 thousand were involved in work-related injuries (ibidem). How can occupational hazards related to MSWM be prevented, thereby protecting workers?

The scientific literature showed the relevance of occupational safety training in promoting safer work environments and demonstrated that engaging training methods (for example hands-on demonstrations) can promote safe work practices, reduce stress, and enhance safety commitment (Ricci et al., 2016). In this sense, the emergence of new technologies presents promising methods. Gamification, namely using game-like elements in training, offers a cost-effective and flexible approach that can provide realistic simulations and promote learner- and user- centered education (Brahm et al., 2016; Mohd et al., 2019; Vigoroso et al., 2021). Game-based safety training activities proved to be effective in reducing workers' risk exposure in many industries (Vigoroso et al., 2021) but the potential of these training methods is still unexplored in the area of waste treatment.

2. The SOHS project

Within the abovementioned context and to provide a contribution for a safer and more sustainable workplace in the waste management sector, the Sustainable Occupational Health and Safety (SOHS) project has been developed. Four Italian academic partners collaborate in the project to create a prototype of a gamified training solution through a human-centered ergonomic approach based on a multidimensional occupational risks assessment (including biomechanical, chemical, biological and psychosocial risk factors) in two waste management plants. The multi-method risk assessment relies on both objective and subjective data, which will be integrated to identify the most critical risk scenarios in the analyzed plants. These will be translated into digital scenarios enriched by the game elements, to train operators in identifying hazards in the plant and in performing correct and safe behaviors. A prototype of the gamified training solution will be developed and its usability will be tested with different groups of workers from the two plants, representing the extremes of human variability (in terms of age, gender, cultural differences and level of work experience).

The SOHS project consists of seven main phases, represented in Fig. 1. All the phases are developed adopting an ergonomic Human Centered Design (HCD) approach (ISO 9241-210:2019). It refers to the focus always being on the user-worker, who is involved in every phase of the design of the gamified training tool as well as his or her physical and cognitive diversity in interactions with tasks, machines, the environment, and other workers. This multi-dimensional perspective is favored by the diverse nature of the scientific and academic partners participating in the project, with many different and well-integrated competencies.

The aim of the present paper is to report the first results of the field analysis and risk assessment phase. Data collection is ongoing, but useful insights are already emerging to address the objectives outlined above.

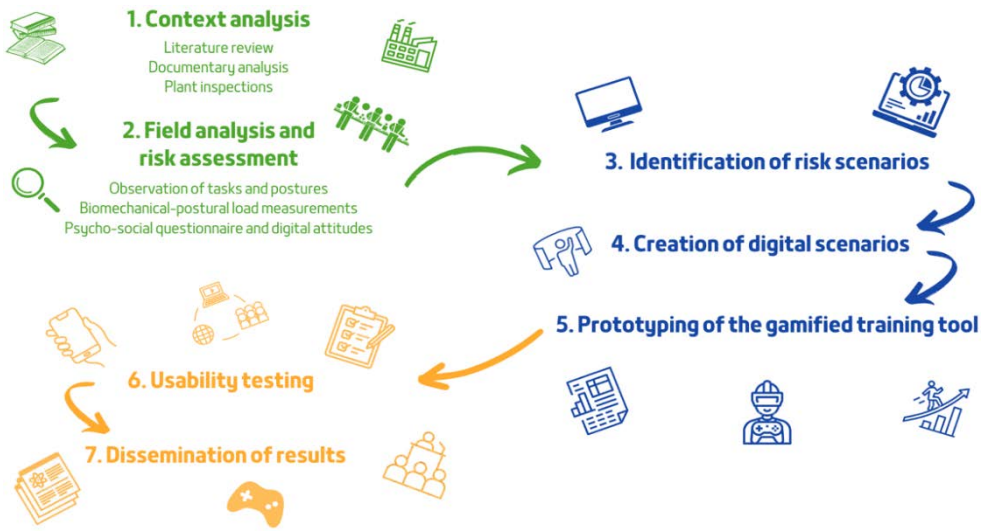


Fig. 1. The SOHS project seven main phases.

3. Materials and methods

3.1. Context of the study

The SOHS project focuses on two case study plants. Both have been identified as representatives of most of the processes and working procedures related to the MSWM, are in Northern Italy and have some common characteristics. The case studies treat different materials (plastic, paper and cardboard), process similar quantities of materials and are similar for the level of mechanization of their activity. Henceforth within this paper, we will identify with "A" the plant that mainly deals with plastic recycling and with "B" the one that mainly deals with paper and cardboard recycling.

Plant A is a social cooperative established to combine social and environmental actions. The activities and services offered in the environmental sector allow both the reduction of waste and consumption and support paths of innovation and cooperation for creative recovery and enhancement of human and natural resources.

Plant B is managed by a leading company in the recovery of recyclable materials. Thanks to the experience acquired in more than 50 years of activity, the company can provide a complete service to find the best solution to waste management, providing the most technologically advanced and suitable equipment for the customers' needs.

About the quantity of waste, that entering plant A in the year 2022 was about 55 thousand tones and that in plant B in the same year was about 46 thousand tones. The amount of recovered waste leaving plant A in the same year is about 53 thousand tones and that from plant B is about 45 thousand tones. Fig. 2a and 2b show the floor plans photo of the two plants.

Fig. 2. Floor plan of Plant A (a) and Plant B (b)

The level of mechanization of the two plants is also similar. The waste is collected from the producers, usually using unloadable containers or compactors provided by the case study companies themselves as part of the service. The incoming material must be separated and isolated from foreign substances and is sorted by material type into different subcategories (e.g. hard/soft plastics, colored/white paper, cardboard, cellophane etc.). Sorting is partly done automatically, but mainly by manual sorting and this is the main activity of the operators involved in the study. The workers at the plants' operating sites mainly perform the tasks of

waste sorting operator and trolley driver. The different types of waste are handled in dedicated areas that form the heart of the firm's activities. The work areas are distributed in different sheds as well as in open areas, where all operational phases take place: waste unloading, mechanical and manual sorting, shredding of paper documents, pressing of papers or plastics, storage and dispatch, in addition to the handling of goods from one area to another. Fig. 3a, 3b and 3c represent some typical workstations in the two plants.

Fig. 3. Workers engaged in manual sorting by conveyor belt placed horizontally (a), by conveyor belt placed obliquely (b) and on the ground (c)

3.2. Data collection and risk assessment methods in case study companies

To conduct the risk assessment, the research team collected data on the actual activities carried out in the two case study companies, involving both the workers and the managers of the two plants. In the meetings with the management, the work organization within the plant was discussed, as well as the mandatory risk assessment document (Documento di Valutazione dei Rischi, DVR), the training activity and the safety culture of the plants.

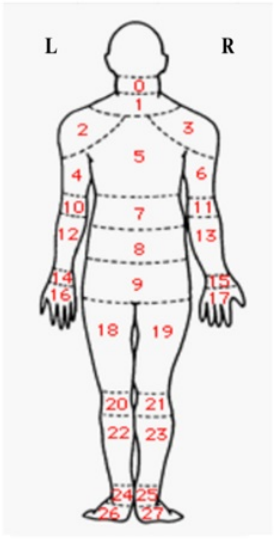
For the risk assessment with workers, three instruments were used: the Rapid Upper Limb Assessment (RULA, McAtamney and Corlett, 1993), Corlett's postural discomfort evaluation form (Corlett, 1995) and an ad-hoc psycho-social questionnaire.

The RULA is a postural targeting method for estimating the risks of work-related upper limb disorders. The RULA gives a quick and systematic assessment of the postural risk for a worker through the direct observation of workers during their daily work tasks. Seven levels of injury risk and four action levels are provided, based on the results of the assessment (Fig. 4). The tasks observed were ground-based manual sorting, in-cab horizontal and oblique non-in-cab manual conveyor belt sorting, and table-based random sorting, with time intervals of about 5 minutes for each worker observed.

The postural discomfort assessment form (Corlett, 1995) allows the worker to indicate in which of the 27 marked body areas he/she perceives discomfort at the end of the work shift, on a scale from "mild" to "unbearable" (Fig. 5). Its completion took about 10 minutes. The RULA is therefore based on data observed by the research team, while the body discomfort map collects data self-reported by the worker.

Action level	RULA score	Interpretation
1	1-2	The person is working in the best posture with no risk of injury from their work posture.
2	3-4	The person is working in a posture that could present some risk of injury from their work posture, and this score most likely is the result of one part of the body being in a deviated and awkward position, so this should be investigated and corrected.
3	5-6	The person is working in a poor posture with a risk of injury from their work posture, and the reasons for this need to be investigated and changed in the near future to prevent an injury.
4	7+	The person is working in the worst posture with an immediate risk of injury from their work posture, and the reasons for this need to be investigated and changed immediately to prevent an injury.

Fig. 4. The four RULA action levels, score and interpretations.



N° Area	Mild Discomfort	Moderate Discomfort	Intense Discomfort	Unbearable Discomfort

Fig. 5. Corlett's postural discomfort assessment form (Corlett, 1995)

As for the psycho-social questionnaire, it was based on previous instruments used in other work sectors (Caffaro et al., 2017; Vigoroso et al., 2024) and then adapted to this study context by the research team. The questionnaire was composed of 15 items divided into two sections entitled “Work and Safety” and “Use and Familiarity with Digital Devices” (in addition to the final section devoted to socio-demographic information). In the first section, aspects related to working conditions and safety climate were addressed on a 4-point rating scale, whereas the second section assessed the adoption/intention to adopt digital devices for both leisure and training objectives (4- and 5-point rating scale). Four open-ended questions addressed workers’ perception of risk in the workplace, the games they prefer to play, and what types of risks they would like to address in gamified training activities. The questionnaire took about 10 minutes to be filled in.

Workers completed both the posture discomfort evaluation form and the questionnaire on paper. Completion took place in a silent setting (the offices of the two case study companies) in which workers had the opportunity to clarify any doubts regarding the meaning of the questions and/or answers directly with the researchers. Before the completion of any of

the three instruments, the workers who participated in the study signed an informed consent. The project and the related data collection activities were approved by the ethical committee of the University of Torino on 30/04/2024 (Prot. n. 0250477).

4. Results and discussion

So far, 31 workers from the two case study plants have participated in the data collection activities. Fifteen workers belonged to company A and sixteen to company B. These included workers mainly engaged in manual sorting on the ground, manual sorting by conveyor belt placed both horizontally and obliquely, manual sample sorting on a table and forklift operators. Twelve workers at the extremes of height and weight variability, in the present sample, were observed with the RULA during their daily work activities. Thirty-one workers completed the postural discomfort assessment form and the psycho-social questionnaire. Their main socio-demographic characteristics are listed in Table 1.

Table 1. Participants' socio-demographic characteristics

Variable		***N***	***Percentage, %***
Gender	**Males**	17	54.84
	Females	12	38.71
Education	**Primary school**	5	13.89
	Middle school	12	33.33
	High school	13	36.11
	Missing	1	2.78
Training courses attended	**0**	2	6.45
	1	5	16.13
	More than 1	24	77.42
		Mean	**Standard deviation**
Age		44.24	10.47
Work experiences (yrs)		7.52	5.03

Regarding safety training, during the meetings the managers of the two plants pointed out the complexity and importance of the regulations governing waste management, as well as the significant degree of risk that some operators face in different tasks, making it necessary for all operational personnel in the sector to participate in various specific trainings. Plant B in particular reported being involved in many projects regarding work safety.

Figures 6 and 7 report the results of the observed postural risks assessment and the perceived postural discomfort assessment form, respectively.

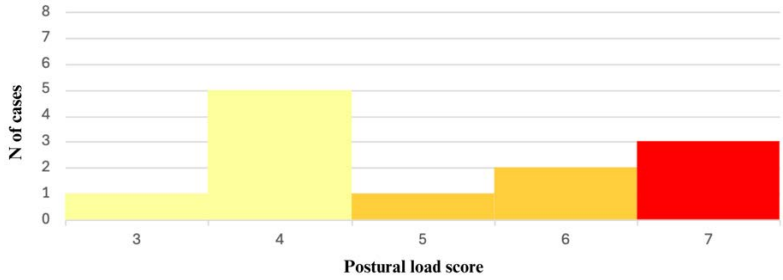
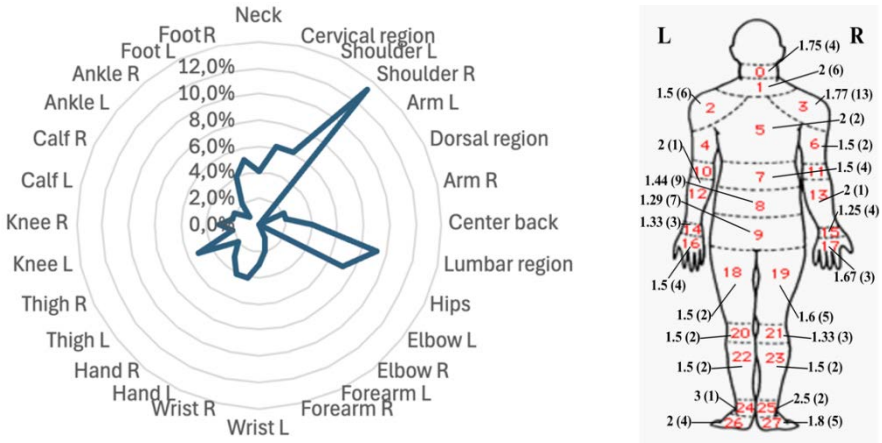


Fig. 6. Observed postural load in twelve workers with the RULA

As it can be seen from Fig. 6, the postures adopted during work were found to be critical according to the risk assessment method adopted, with high scores on the RULA scale for half of the workers observed (6 out of 12): in three cases they assumed postures and body angles for which investigations and changes were needed soon (scores 5 and 6) but in three cases the modification intervention was urgent or even immediate (score 7+). It was also observed that postural overload depends on workers' anthropometric differences and the way in which workers carry out their activities. Therefore, not only small adjustments to workstations are recommended, but also training in correct postures and movements for primary prevention.

Figures 7a and b report the frequency and intensity of body discomfort for the 27 areas of the Corlett assessment form (1995). Only two workers declared no discomfort at all it, while six indicated it in only one body area and the remaining twenty-four from two to ten body areas. In decreasing order of frequency, discomfort was reported on: right shoulder and lumbar region and hips; cervical region and left shoulder, right foot and right tight (Fig. 7a). Workers reported frequent and middle/high discomfort in the areas of right shoulder, cervical and lumbar region while they declared moderate discomfort in left shoulder and hips; in the case of ankles, feet and neck the frequency was limited to a few subjects but the intensity was high (Fig. 7b).



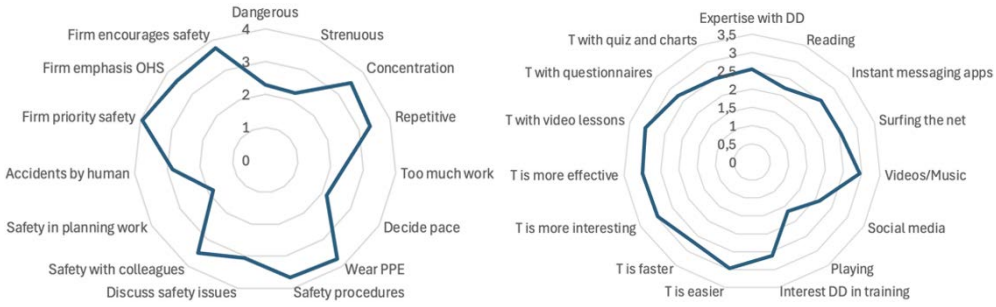
(a) (b)

Fig. 7. Perceived discomfort (N=31 workers) in the 27 body areas of the Corlett assessment form (1995): by frequency (a) and by average intensity for each area (b). The number of workers who reported the discomfort is in brackets.

From these first results, some ameliorative changes in the workstations and work processes can be proposed to the case study companies, such as:

- Place stools/seats to alternate position.
- Adopt arm clamps for picking/pre-selection and to reduce bending.
- Adopt increased use of PPE (e.g. earplugs/headphones and cut-resistant gloves).
- Install washable rubber/plastic guards where not present.
- Relocate some waste containers (closer and lower to the operators' position).
- Uniform the heights of the containers where necessary.
- Install removable lifting platforms where necessary.
- Include specific cleaning times at mid/end of shift.

Regarding the psycho-social questionnaire, the results are shown in Fig. 8.



(a) (b)

Fig. 8. Results from the questionnaire administered: Perceived working conditions and safety climate (a); Self-reported use and familiarity with digital device and predisposition to training with digital devices (b). *Note.* DD = Digital Device, T = Training

If we compare the RULA results with those from the perceived postural discomfort form and the psycho-social questionnaire, it may be noted that in both case study plants, workers who were observed to have a 5+ upper limb load are on average taller and perceived discomfort in fewer areas of the body. The same workers also reported that they perceive their work as less dangerous, strenuous and repetitive on average than those who were observed to have a 5- upper limb load. These discrepancies between observed and self-reported data stress the importance of a multi-method risk assessment, to be able to identify the gaps between objective and subjective criticalities and develop targeted interventions (Zare et al., 2021).

As it can be seen from Fig. 8a, workers considered their work dangerous and strenuous slightly above the average. Workers also perceived their work as requiring great concentration and attention, as well as being very repetitive. The repetitive movements are consistent with workers' self-reported levels of discomfort on the Corlett scale and the positions observed with 5+ values with the RULA. Furthermore, workers perceived the company as attentive to safety and health at work and declared they were compliant with the use of PPE and safety procedures. Despite this, they seemed to lack safety citizenship behaviors (Didla et al., 2009), since they reported to consider little safety aspects when planning their daily work and not often discuss safety issues with colleagues. These results seem to show that other initiatives are needed at organizational level to promote a safety culture which can become part of workers' routine and integrated in their everyday work behaviors, in line with previous results in other industries (Caffaro et al., 2017).

Regarding familiarity with and perception of digital devices (Fig. 8b) workers considered themselves experts with digital devices above the average. Workers said they were familiar with digital devices, but they also stated that they use them little to play games. The SOHS project, which has as one of its main goals to use gamification in training activities, will have to answer the question of how to be able to combine these different workers' statements. This could be fostered by workers' stated good predisposition to training through digital devices (easier, faster, more interesting and more effective with use of video lessons with questionnaires, quizzes and charts to carry out training activities) and by the large number of activities they declared to perform on digital devices (reading, using instant messaging apps, surfing the net, listening to music/watching videos, using social media).

5. Concluding remarks

The initial findings of the SOHS project demonstrate significant discrepancies between observed and self-reported work conditions and behaviors among workers in the waste management sector. The multi-method risk assessment revealed critical postural risks, with half of the workers observed showing high RULA scores, underscoring the urgent need for workstation adjustments and targeted ergonomic interventions. Notably, workers' perceptions of discomfort varied, with frequent complaints about shoulders, lumbar regions, and hips.

Despite workers acknowledging the hazardous and strenuous nature of their tasks, the study highlighted a lack of proactive safety engagement. Although the workers reported compliance with PPE usage and safety procedures, the absence of safety citizenship behaviors suggests a need for organizational measures to enhance safety culture and integrate it into daily routines.

The results also indicate a positive attitude toward digital training, despite limited engagement with game-based tools. This presents an opportunity for the SOHS project to develop an engaging gamified training tool tailored to the workforce's needs and preferences. The planned game scenarios, incorporating realistic work conditions with a system of levels, rewards, and penalties, aim to bridge the gap between observed and perceived risks, promoting safer work practices through interactive learning.

These preliminary conclusions highlight the potential for innovative, technology-driven training solutions to enhance occupational safety in hazardous sectors like waste management. Further research and validation of the gamified training prototype will determine its effectiveness and scalability for broader industry application.

Acknowledgements

The SOHS project (PRIN 2022, COD 20227TS4WN) is funded by the European Union, NextGenerationEU.

References

Brahm F., Singer M., (2016), Is more engaging safety training always better in reducing accidents? Evidence of self-selection from Chilean panel data, *Journal of Safety Research*, **47**, 85–92.

Caffaro F., Micheletti Cremasco M., Roccato M., Cavallo E., (2017), It does not occur by chance: A mediation model of the influence of workers' characteristics, work environment factors, and near misses on agricultural machinery-related accidents, *International Journal of Occupational and Environmental Health*, **23**, 52–59.

Corlett E.N., (1995), *The Evaluation of Posture and its Effects*, In: *Evaluation of Human Work*, Wilson J.R., Corlett E.N. (Eds.), Taylor and Francis, London, 662–713.

Didla S., Mearns K., Flin R., (2009), Safety citizenship behaviour: A proactive approach to risk management, *Journal of Risk Research*, **12**, 475–483.

EU-OSHA, (2009), Expert forecast on emerging chemical risks related to occupational safety and health: European Risk Observatory Report, European Agency for Safety and Health at Work Online at: https://osha.europa.eu/en/publications/report-expert-forecast-emerging-chemical-risks-related-occupational-safety-and-health/view.

EU-OSHA (), (2019), Biological agents and work-related diseases: Results of a literature review, expert survey and analysis of monitoring systems: Technical Report. European Agency for Safety and Health at Work Online at: https://osha.europa.eu/sites/default/files/Biological_agents_and_work_related_diseases_results%20_literature_review_summary.pdf.

Gregson N., Crang M., Botticello J., Calestani M., Krzywoszynska A., (2016), Doing the 'dirty work' of the green economy: Resource recovery and migrant labour in the EU, *European Urban and Regional Studies*, **23**, 541–555.

INAIL, (2021), Problematiche di Sicurezza e Dinamiche Infortunistiche nel Settore Rifiuti: InforMO – Sorveglianza degli Infortuni Mortali. Istituto Nazionale Assicurazione contro gli Infortuni sul Lavoro. Online at: https://certifico.com/sicurezza-lavoro/documenti-sicurezza/63-guide-sicurezza-lavoro-inail/13389-infor-mo-problematiche-di-sicurezza-e-dinamiche-infortunistiche-settore-rifiuti#allegati.

ISO, (2019), International standard ISO 9241-210:2019, Ergonomics of human-system interaction: Part 210: Human-centred design for interactive systems, Edition 2, 2019-07. International Organization for Standardization, Online at: https://www.iso.org/standard/77520.html.

Kaza S., Yao L., Bhada-Tata P., Van Woerden F., (2018), What a waste 2.0: A global snapshot of solid waste management to 2050, *World Bank*, Washington, DC. Online at: https://openknowledge.worldbank.org/bitstream/handle/10986/30317/211329ov.pdf.

Ricci F., Chiesi A., Bisio C., Panari C., Pelosi A., (2016), Effectiveness of occupational health and safety training: A systematic review with meta-analysis, *Journal of Workplace Learning*, **28**, 355–377.

McAtamney L., Corlett E.N., (1993), RULA: A survey method for the investigation of work-related upper limb disorders, *Applied Ergonomics*, **24**, 91–99.

Mohd N.I., Ali K.N., Ebrahimi S.S., Ahmad Fauzi A.F.A., (2019), Understanding the level of self-directed learning and decision-making style of construction-related workers, *International Journal of Interactive Mobile Technologies*, **13**, 44–53.

Song J., Feng R., Yue C., Shao Y., Han J., Xing J., Yang W., (2022), Reinforced urban waste management for resource, energy and environmental benefits: China's regional potentials, *Resources, Conservation and Recycling*, **178**, 106083.

Szulc J., Okrasa M., Majchrzycka K., Sulyok M., Nowak A., Szponar B., Górczyńska A., Ryngajłło M., Gutarowska B., (2022), Microbiological and toxicological hazard assessment in a waste sorting plant and proper respiratory protection, *Journal of Environmental Management*, **303**, 114257, https://doi.org/10.1016/j.jenvman.2021.114257.

Vigoroso L., Caffaro F., Micheletti Cremasco M., Cavallo E., (2021), Innovating occupational safety training: A scoping review on digital games and possible applications in agriculture, *International Journal of Environmental Research and Public Health*, **18**, 1868, https://doi.org/10.3390/ijerph18041868.

Vigoroso L., Roccato M., Cavallo E., Caffaro F., (2024), Intention to adopt digital games for safety training in young farm operators: The role of ease of use, perceived usefulness, and game design characteristics, *International Journal of Human–Computer Interaction*, https://doi.org/10.1080/10447318.2024.2310353.

Zare M., Norval M., Bodin J., Roquelaure Y., (2021), Differences between risk situations identified using a self-reported questionnaire and an observational method, *Work*, **68**, 1–11.