Occupational hazard management in grain storage units

Gestão de riscos ocupacionais em unidades de armazenagem de grãos

Peterson Diego Kunh¹
Divair Christ²
Silvia Renata Machado Coelho³
Sergio Adelar Brun⁴
Carlos Aparecido Fernandes⁵
Reginaldo Borges⁶
Edson Hermenegildo Pereira Junior⁷
Cidmar Ortiz dos Santos⁸

¹ PhD in Agricultural Engineering, Universidade Estadual do Oeste do Paraná (UNIOESTE), Av. Brasil, 4232, Independência, Medianeira - PR, CEP: 85884-000. E-mail: petersond@utfpr.edu.br
Orcid: https://orcid.org/0000-0003-2641-7464

² Doctor of Food Engineering, Universidade Estadual de Campinas (UNICAMP), Rua Universitária, 1619, Cascavel - PR, CEP: 85819-110. E-mail: divair.christ@unioeste.br
Orcid: https://orcid.org/0000-0001-7179-4336

³ PhD in Food Sciences, Universidade Estadual de Londrina (UEL), Rua Universitária, 1619, Cascavel - PR, CEP: 85819-110. E-mail: silvia.coelho@unioeste.br Orcid: https://orcid.org/0000-0002-1614-8021

⁴ Doutor em Administração, Universidade Federal de Santa Catarina (UFSC), Av. Brasil, 4232, Independência, Medianeira - PR, CEP: 85884-000. E-mail: sergiobrun@utfpr.edu.br
Orcid: https://orcid.org/0000-0002-8674-331X

⁵ Doctor of Production Engineering, Universidade Federal de Santa Catarina (UFSC), Brasil. Av. Brasil, 4232, Independência, Medianeira - PR, CEP: 85884-000. E-mail: carlosfernandes@utfpr.edu.br
Orcid: https://orcid.org/0000-0001-7675-8529

⁶ PhD in Production and Systems Engineering, Pontifícia Universidade Católica do Paraná (PUC-PR), Av. Brasil, 4232, Independência, Medianeira - PR, CEP: 85884-000. E-mail: rborges@utfpr.edu.br
Orcid: https://orcid.org/0000-0001-9314-6399

⁷ PhD in Agricultural Engineering, Universidade Estadual do Oeste do Paraná (UNIOESTE), Av. Brasil, 4232, Independência, Medianeira - PR, CEP: 85884-000. E-mail: edsonhjunior@utfpr.edu.br
Orcid: https://orcid.org/0000-0003-4876-5611

⁸ Doctor of Science and Technology Teaching, Universidade Tecnológica Federal do Paraná - campus Ponta Grossa (UTFPR), Av. Brasil, 4232, Independência, Medianeira - PR, CEP: 85884-000. E-mail: cidmar@utfpr.edu.br Orcid: https://orcid.org/0000-0002-1727-3676
Abstract
With the expansion of global grain production, in which Brazil ranks 4th with 7.8%, and, in light of the estimated production for the 2022/2023 harvest of 309.9 million tons, there is a deficit in storage capacity, currently representing 60.9% of production. Given the importance and expectation of expanding, it is necessary to prevent illnesses and accidents linked to this process. This work aims to develop an occupational hazards management model during the grain storage and drying processes, to determine the hazards that workers are exposed in their activities. The methodology was applied in western Paraná, Brazil, in a grain drying and storage unit during the inter-harvest and harvest periods to analyze, identify, evaluate, prioritize, and develop an action plan for the hazards. Among the hazards identified in the literature and at the site, exposure to heat and noise was evaluated, generating a score that represents the hazard situation in the environment. Of the 104 possible points in the evaluation, occupational exposure to heat obtained the lowest score of 70 (regular level), compared to noise with a score of 90 (normal level). For solving identified non-conformities, it can be highlight the replacement of thermal protection gloves and installation of a on-site temperature and humidity meter. With the methodology, it is possible to evaluate hazards and propose mechanisms that lead to their resolution, prioritizing the most critical levels according to the generated score.


Resumo
Com a expansão da produção mundial de grãos, onde o Brasil ocupa a 4ª posição com 7,8%, e a produção estimada para safra 2022/2023 de 309,9 milhões de toneladas, observa-se um déficit da capacidade de armazenagem que atualmente representa 60,9% da produção. Visto a importância e expectativa de expansão, é necessário evitar o adoecimento e os acidentes vinculados a este processo. Este trabalho tem como objetivo desenvolver um modelo de gestão de riscos ocupacionais durante os processos de armazenamento e secagem de grãos, para determinar os perigos aos quais os trabalhadores estão expostos em suas atividades. A metodologia foi aplicada no oeste do Paraná em uma unidade de secagem e armazenagem de grãos durante o período entre safra e safra para analisar, identificar, avaliar, priorizar e elaborar um plano de ação dos riscos. Dentre os riscos identificados na literatura e no local, avaliou-se a exposição ao calor e ruído gerando uma pontuação que representa a situação do risco no ambiente. Dos 104 pontos possíveis na avaliação, a exposição ocupacional ao calor obteve a menor pontuação 70 (nível regular) quando comparado ao ruído com 90 pontos (nível...
normal). Para resolução das não conformidades identificadas pode-se destacar a troca da luva de proteção contra agentes térmicos e instalação de um medidor de temperatura e umidade no ambiente. Com a metodologia é possível avaliar os riscos e propor mecanismos para auxiliar na resolução, priorizando com a pontuação gerada, as de níveis mais críticos. 


**Introduction**

The world grain production for 2022 is estimated at 2.774 billion tons, according to a survey by The Food and Agriculture Organization of the United Nations (FAO), 16 million less compared to the record attained in 2021. The leading countries in global production are China, the United States of America, India, and Brazil, which are responsible for 54% of total production, with Brazil ranking 4th with 7.8% of global production (Estadão, 2022; Exame, 2022; FAO, 2023).

These numbers show the importance of agribusiness for the global economy. Among the various processes involved in grain production, post-harvest activities (pre-processing and storage) stand out as a step of the production chain that uses various technologies, whose goal is to maintain the quality and characteristics of the products produced in the field.

Brazil ended the first semester of 2022 with an available storage capacity of 188.8 million tons, 3% higher compared to the previous semester. Mato Grosso has the largest storage capacity in the country, with 46.9 million tons, followed by the states of Rio Grande do Sul and Paraná. Silos represent 50.9% of the useful capacity, with 96.1 million tons, grain warehouses and bulk storage warehouses representing 37.1%, while conventional, structural, and inflatable warehouses contribute 12% to national storage (IBGE, 2022a).

The main agricultural products in stock in storage units are soy, corn, rice, wheat, and coffee, which represent 95.8% of the total stored in the first semester of 2022; with cotton, black beans, colored beans, and other grains and seeds accounting for the remainder (IBGE, 2022a; 2022b).

With the record production of the 2021/2022 harvest of 271.2 million tons of grains, with an increase of 14.5 million tons compared to the previous cycle and an estimated production for the 2022/2023 harvest of 309.9 million tons, storage capacity represents 60.9%
of current production, and this sector has great expansion potential (CONAB, 2022a; 2022b; 2023).

According to Gresele (2020), the growth of Brazilian static capacity went from 106.5 million tons in 2005 to 169.8 million tons in 2019, an increase of 63.3 million tons (59%), which represents an average increase of 3.96% per year over 15 years.

Given the need and expected expansion of grain storage units, it is essential to avoid illness and accidents in the work environment. There are few studies related to occupational hazards developed in post-harvest activities in pre-processing and grain storage units. Thus, such studies are recent in identifying the causes of occupational incidents in this line of work (Geng & Dee, 2018; Kakhki et al., 2019; Chen et al., 2020; Bellochio & Coradi, 2022).

Due to the strategic position of this sector for the country's economy and the occupational hazards to which workers are exposed, a methodology was developed and applied that will assist companies in identifying, evaluating, prioritizing, and neutralizing the occupational hazards present in the grain storage and drying process, with a focus on reducing accidents and illness.

**Methodology**

A systematic literature review was conducted using the multicriteria Method Ordinatio methodology to guide the research question: "What are the methodologies for managing and evaluating occupational hazards used in grain drying and storage operations?" (Pagani et al., 2015; Campos et al., 2018; Pagani et al., 2018; Paula et al., 2020).

The study focused on post-harvest operations and occupational hazards in grain storage units that may result in accidents and illness. The systematic search was performed in the Scopus, Science Direct, Web of Science, and Scielo databases on 09/10/2022.

The following database search syntax was used: ("storage facilities" OR "grain storage units " OR " grain operations" OR "grain storage plants" OR "grain silo*") AND ("occupational safety" OR "occupational accident" OR "occupational hazards" OR "work accident"). Initially no restrictions were applied, resulting in 35 Scopus, 1 Science Direct, 11 Web of Science and 0 articles in Scielo. Applying the filtering procedures to remove duplicate articles, conference papers, books, book chapters and articles with topics outside the scope, by reading the title, abstract and keywords, resulted in 18 articles selected.

The selected articles were ranked considering the journal’s impact factor, number of citations and year of publication. The selected articles were systematically read and analyzed
to obtain information about the development of the research, methodology and occupational risks identified/analyzed.

In parallel, the legislation that addresses the most frequent risks in the sector, measurement mechanisms, and tolerance limits for each situation was verified, allowing for the preparation of a script to evaluate on-site environmental risks. The selection criteria recommended by ABNT NBR ISO/IEC 31010 - Risk management - Techniques for the risk assessment process (ABNT, 2012) were used.

Through the use of proactive indicators it is possible to measure and establish preventive actions, acting before the occurrence of unwanted consequences, reducing risks in the work environment (BERMUDES, 2018).

With visits to a grain drying and storage unit in November 2022 and February 2023, respectively inter-harvest and harvest periods, it was possible to validate the proposed methodology with the participation of the company's Safety and Occupational Medicine Specialized Service (SESMT). Among the risks identified in the literature and on site, we initially evaluated the exposure to heat and noise in the activities performed.

The company's facility is located in western Paraná, Brazil. The unit was purchased in 2020 and has a static storage capacity of 5,000 tons of grain, distributed across four silos.

Based on current legislation, inspection spreadsheets were prepared where each evaluative question has its respective legal foundation, presented in Chart 1 (heat) and Chart 2 (noise):

<table>
<thead>
<tr>
<th>Item</th>
<th>Pergunta avaliativa</th>
<th>Used Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Is the obtained IBUTG (mean) value below the action level of occupational exposure?</td>
<td>NR 9 - annex 3 - 3.1 The organization must adopt preventive measures so that occupational exposure to heat does not cause adverse effects on the worker's health, (action level).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NR 15 - annex 3 - 2.3 The activities or operations performed in closed environments or environments with artificial heat source are characterized as unhealthy whenever the measured Wet Bulb Thermometer Globe Index (IBUTG) (average) exceeds the occupational exposure limits established based on the IBUTG presented in Table 1 and determined based on the metabolic rate of the activities, presented in Table 2 of NR 15, annex 3.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NHO 06 - 4 - Occupational Exposure Limit: maximum value of IBUTG related to the average metabolic rate (M). It represents the conditions under which it is believed that most workers can be exposed, repeatedly, throughout their working life, without suffering adverse effects on their health.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.3 The occupational exposure limit to heat is established on the basis of the weighted average IBUTG and the weighted average metabolic rate (M). This is an hourly limit and, therefore, must be respected in any period of 60 consecutive minutes throughout the</td>
</tr>
<tr>
<td>Item</td>
<td>Pergunta avaliativa</td>
<td>Used Standard</td>
</tr>
<tr>
<td>------</td>
<td>------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>2</td>
<td>Does the company make fresh drinking water available and encourage its intake?</td>
<td>NR 9 - annex 3 - 4.1.1 Whenever the action levels for occupational exposure to heat, established in Table 1, are exceeded, the employer must adopt one or more of the following measures: a) make fresh drinking water (or other appropriate replacement liquid) available and encourage its intake.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NHO 06 - 10.1 Preventive measures are actions that aim at minimizing the probability of occupational exposures to heat reaching the region of uncertainty, which may cause damage to the worker's health. Making water and mineral salts available for adequate replacement of sweat loss, according to orientation.</td>
</tr>
<tr>
<td>3</td>
<td>Are the heaviest jobs scheduled preferably in the periods with the mildest thermal conditions?</td>
<td>NR 9 - annex 3 - 4.1.1 Whenever the action levels for occupational exposure to heat, established in Table 1, are exceeded, the employer must adopt one or more of the following measures: b) schedule the heaviest work (above 414W - four hundred and fourteen watts), preferably in periods with milder thermal conditions, provided that no additional risks occur in these periods.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NHO 06 - 10.1 Care and procedures recommended to reduce physiological overload; possible limitations of protection of control measures, their importance and correct use;</td>
</tr>
<tr>
<td>4</td>
<td>Is work clothing provided that is adequate and adapted to the type of exposure and the nature of the activity?</td>
<td>NR 9 - annex 3 - 4.1.2 For closed environments or with artificial heat sources, besides sub-item 4.1.1, the employer must provide work clothes adapted to the type of exposure and the nature of the activity.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NHO 06 - 5.5 The clothes used can influence the exchange of heat between the body and the environment and, therefore, should be considered in the evaluation of occupational exposure to heat. Therefore, the correction for clothing must be made whenever the worker uses clothes or PPE different from traditional uniforms (composed of long-sleeved pants and shirt) that impair the free circulation of air over the body surface, hindering these exchanges of heat with the environment.</td>
</tr>
<tr>
<td>5</td>
<td>Is it possible to alternate operations that generate exposures to higher levels of heat with those that have no or lower exposures, resulting in reduced exposure?</td>
<td>NR 9 - annex 3 - 4.2.2 When the exposure limits established in Table 2 are exceeded, the employer must adopt one or more of the following corrective measures: b) alternate operations that generate exposure to higher levels of heat with others that do not present exposure or involve exposure at lower levels, resulting in reduced exposure.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NHO 06 - 10.2 Alternation of operations that generate exposure to higher heat levels with others that do not present exposures or imply exposures at lower levels, resulting in the reduction of the hourly exposure.</td>
</tr>
<tr>
<td>6</td>
<td>Does the company provide access to places, including natural, thermally milder places, that allow for spontaneous breaks?</td>
<td>NR 9 - annex 3 - 4.2.2 When the exposure limits established in Table 2 are exceeded, the employer must adopt one or more of the following corrective measures: c) provide access to places, including natural, thermally milder ones, which allow spontaneous breaks, enabling thermal recovery in activities carried out in open locations and away from any buildings or natural or artificial structures.</td>
</tr>
</tbody>
</table>
|      |                                                                                     | NHO 06 - 10.2 Availability of air-conditioned or thermally milder
<table>
<thead>
<tr>
<th>Item</th>
<th>Pergunta avaliativa</th>
<th>Used Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Are there mechanisms to control the temperature or emissivity of the heat source?</td>
<td>NR 9 - annex 3 - 4.2.2.1 For closed environments or with artificial heat sources, in addition to item 4.2.2, the employer must: a) adapt work places and stations; b) reduce the temperature or emissivity of heat sources.</td>
</tr>
<tr>
<td>8</td>
<td>Is as a barrier for radiant heat used?</td>
<td>NR 9 - annex 3 - 4.2.2.1 For closed environments or with artificial heat sources, in addition to item 4.2.2, the employer shall (c) use barriers for radiant heat. NHO 06 - 10.2 Use of reflective or absorbent barriers.</td>
</tr>
<tr>
<td>9</td>
<td>Does it have a workplace air ventilation system?</td>
<td>NR 9 - annex 3 - 4.2.2.1 For closed environments or with artificial heat sources, besides item 3.2.2, the employer shall (d) adapt the air ventilation system.</td>
</tr>
<tr>
<td>10</td>
<td>Does it have mechanisms to control and adjust the temperature and relative humidity of the air in the environment?</td>
<td>NR 9 - annex 3 - 4.2.2.1 For closed environments or with artificial heat sources, besides item 3.2.2, the employer must (e) adjust the temperature and relative humidity of the air.</td>
</tr>
<tr>
<td>11</td>
<td>Is there Collective Protection Equipment implemented and/or administrative or organizational measures?</td>
<td>This item fits as a complementary protection device.</td>
</tr>
</tbody>
</table>

**Chart 1: Legal basis of the heat evaluation questions**

*Source: Authors creation*
<table>
<thead>
<tr>
<th>Item</th>
<th>Pergunta avaliativa</th>
<th>Used Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Has a record of PPE training been kept?</td>
<td>NR 1 - 1.7 Capacity building and training in Health and Safety at Work; 1.7.1.1 At the end of the initial, periodic or occasional training sessions, as established in the NR, a certificate must be issued containing the name and signature of the worker, program content, work load, date, place where the training was carried out, the name and qualifications of the instructors and the signature of the person technically responsible for the training.</td>
</tr>
<tr>
<td>6</td>
<td>Is periodic verification of PPE use being carried out?</td>
<td>NR6 - 6.5.1 As far as PPE is concerned, the organization is responsible for: b) instructing and training the employee.</td>
</tr>
<tr>
<td>7</td>
<td>Is the Approval Certificate (CA) within the validity period?</td>
<td>NR 6 - 6.9.2.1 The PPE shall be marketed with a valid Approval Certificate - AC. 6.9.3 All PPE shall bear, in indelible, legible and visible characters, markings with the trade name of the manufacturer or importer, the manufacturing batch and the CA number. 6.9.3.1 If it is impossible to comply with the provisions of item 6.9.3, alternative means of recording may be authorized, and this shall appear on the CA.</td>
</tr>
<tr>
<td>8</td>
<td>Does the worker have an adequate place to store the IPE?</td>
<td>NR 6 - 6.5.1 Regarding PPE, the organization is responsible for: f) taking responsibility for cleaning and periodic maintenance, when applicable these procedures, in accordance with the information provided by the manufacturer or importer. 6.6 Workers' responsibilities: c) be responsible for cleaning, safekeeping and conservation.</td>
</tr>
<tr>
<td>9</td>
<td>Does the worker have an adequate place to clean the IPE?</td>
<td>NR 6 - item 8 - 6.5.1 f) and item 6.6 paragraph c).</td>
</tr>
<tr>
<td>10</td>
<td>Is the resulting Sound Pressure Level (SPL) with the use of PPE below 80 dB(A)?</td>
<td>NR 9 – item1 – 9.6.1 c) and item 9.6.1.2 NHO 01 – item 1 – 5.1.1.2.</td>
</tr>
<tr>
<td>11</td>
<td>Is there Collective Protective Equipment implemented and/or administrative or organizational measures?</td>
<td>This item fits as a complementary protection device.</td>
</tr>
</tbody>
</table>

Chart 2: Legal basis of the noise assessment questions
Source: Authors creation

Of the 11 questions that make up the tables, question 1 refers to quantitative evaluation. The quantitative evaluation of occupational exposure to heat is carried out through the Wet Bulb Globe Temperature (WBGT) index, related to the Metabolic Rate (M) of the physical activity performed by the worker. The equipment used was the IBUTG Net®.temp° thermal
stress meter, together with the Chrompack company's remote control center, Commander, as shown in Figure 1A.

Figure 1: A) Caloric and central stress Commander meter; B) SmartdB audiodosimeters
Source: Authors creation

To measure noise, two SmartdB sound level meters, shown in Figure 1B, and a Chrompack Smartcal acoustic calibrator were used. Each equipment simultaneously performs two measurements, taking into account the parameters of the Occupational Hygiene Standard (NHO 01) - Evaluation of occupational exposure to noise (dosimeter 1) and Regulatory Standard (NR 15) - Unhealthy activities and operations annex n° 1 tolerance limits for continuous and intermittent noise (dosimeter 2), as seen in Table 1.

<table>
<thead>
<tr>
<th>Sound Level Meters</th>
<th>Criterion Level</th>
<th>Threshold Level</th>
<th>Doubling Rate</th>
<th>Frequency</th>
<th>Time Weighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dosimeter 1</td>
<td>85 dB</td>
<td>80 dB</td>
<td>3 dB</td>
<td>A</td>
<td>Slow</td>
</tr>
<tr>
<td>Dosimeter 2</td>
<td>85 dB</td>
<td>80 dB</td>
<td>5 dB</td>
<td>A</td>
<td>Slow</td>
</tr>
</tbody>
</table>

Table 1: Regulation parameters used in each equipment
Source: SIT, 2019

The criterion level column represents the tolerance limit of 85 dB for occupational exposure to noise when the worker is without protection during an 8-hour daily work shift. The threshold level is the noise level from which values should be computed for integration to determine the exposure dose or the average level, which is 80 dB. Doubling rate represents the doubling of the dose, NHO 01: 3 dB and NR 15: 5 dB. Frequency (A) and time weighting (slow) represent equipment settings for measuring continuous and intermittent noise.

For the quantitative evaluation of heat and noise, the following procedures were carried out:
Instrument in evaluation condition: a prior inspection of the equipment was performed regarding electromechanical integrity, battery charge, and calibration;

Minimum specifications of the meters: the evaluation of heat exposure is obtained through the wet-bulb temperature (tbn), globe temperature (tg), and dry-bulb temperature (tbs), to calculate IBUTG, meeting the minimum equipment prerequisites set out in NHO 06 - Evaluation of occupational exposure to heat. The noise dosimeters comply with Standard ANSI S1.25-1991 and have a minimum Type 2 classification, adjusted with the following parameters: weighting circuit "A"; slow response circuit; reference criterion – 85 dB, corresponding to 100% dose for an 8-hour exposure; integration threshold level – 80 dB; minimum measurement range – 80 to 115 dB (A); doubling rate – 3 (q=3) for NHO 01 or 5 (q=5) for NR 15; indication of levels higher than 115 dB (Fundacentro, 2001);

To measure heat, the wick (wet-bulb thermometer) was previously humidified, which should occur by capillarity, and the system was stabilized before starting recording. Noise measurements were taken with the microphone positioned within the worker's auditory zone, over the shoulder and attached to the clothing;

Before taking measurements, workers were informed of the purpose of the work, that the measurements do not record conversations, that the equipment can only be removed by the evaluator, and that they should not move or obstruct the equipment;

After measurements, calibrations of noise equipment were performed, which remained within the tolerance range of ± 1 dB.

The quantitative (question 1) and qualitative (questions 2 - 11) evaluations of Charts 1 and 2 were carried out on 11/28/2022 and 02/23/2023, with a sampling duration that represented the worker's daily exposure. The application of each inspection sheet generated a score that conveyed the situation of the respective hazard at the evaluated site.

To verify the level of urgency to correct the identified hazard situations and subsequently prioritize those with more critical levels, we used an evaluation indicator that follows the following precepts:

Each questionnaire could have a final score of 100 points, if it meets all the evaluated items, and may receive a bonus of 4 points when it has some complementary protection device (question 11 of charts 1 and 2) and get a maximum score of 104 points.

During the inspection, for items in non-compliance with the standard is assigned the word "NO", with a score of zero. The items in compliance are assigned
the word "YES" or "DOES NOT APPLY", whose weight for each question corresponds to the maximum score that can be obtained in the evaluation (100 points) divided by the number of items evaluated (10). In this study, 10 points were stipulated for each question. Different weights can be given to each evaluated item, according to its importance.

- A final score should be interpreted as follows: Points from 0 to 40 - is at critical level and the corrections should be urgently executed; from 41 to 60 - alert level, and it is recommended to schedule correction; from 61 to 80 points - regular level, in good condition, but with some restrictions to the standard; from 81 to 104 - normal level, in good condition, but with few or no restrictions to the standard.

The score portrays the situation of the respective hazard at the evaluated site. Based on the score obtained, it is possible to individually assess hazards and propose an action plan to help solve the non-conformities identified, prioritizing those with more critical levels.

**Analysis and Discussion of Results**

Before the grains are stored in the silos, the product goes through the processing phase, which consists in the removal of excess moisture and impurities, followed by the grains being weighed and unloaded. For these steps, the storage units (Figure 2A) have cleaning machines and grain dryers (Gresele, 2020; Bellochio & Coradi, 2022).

![Figure 2: A) Aerial view of the unit; B) sector of the furnaces in the inter-harvest period](image)

Source: Authors creation

The stages that the product goes through before being stored can be classified as receiving, cleaning, and drying.
At the receiving stage, the product is received, weighed, sampled, and classified. During the cleaning process the impurities are removed in two stages: removal of the larger grains and then the smaller grains, performed by mechanical conveyors. In this stage the most frequent occupational hazards are related to the movement of machines and equipment, dust and noise. The drying of the product consists in passing the mass of heated air through the mass of grains, an activity performed to reduce the humidity to acceptable levels. At this stage furnaces are used, Figure 2B, and the passage of air through the mass of grains is performed through exhausts, so the high temperatures used in the process must be inspected, at this stage the heat represents hazard to the worker (Mota, 2015; Nunes, 2019; Gresele, 2020; Bellochio & Coradi, 2022).

In the last stage, to perform the storage of grains, there is a wide variety of models of silos, which can be classified as horizontal, vertical, V-bottom and semi-V-bottom, among others. At this stage there is the hazard of falling from different levels, confined spaces, dust, and engulfment. The need to store products in silos is due to the need to store large quantities of products, long periods of time and reduced physical space (Ficanha, 2020; Bellochio & Coradi, 2022).

Most accidents in grain storage units may be associated with the complexity of the structures present in the processes and their operations, which offer hazards of serious and fatal injuries (Geng & Dee, 2018; Dias et al., 2019; Bellochio & Coradi, 2022).

During the grain storage process, workers may be exposed to several hazard situations, such as physical (noise, vibrations and heat), chemical (gases, dust and confined space), accident (engulfment, falls from different levels, machinery, fire and explosion), ergonomic (load transport, posture and repetitive movements) and biological (bacteria, parasites and viruses) that, when exceeded the tolerance limits, can cause diseases, accidents and death. The lack of information about preventive actions is still the biggest cause of accidents at these sites (Gouveia et al., 2013; Mota, 2015; Issa et al., 2017; Bermudes, 2018; Geng & Dee, 2018; Dias et al., 2019; Santos et al., 2020; Bellochio & Coradi, 2022).

According to data obtained in the unit, the harvest period was considered to be the months of January, February and March (soybeans), July and August (corn) and September (wheat), a period that increases the demand for activities in the unit, as illustrated in Figure 3A and B.
In Figure 3A is the image of the sector where the two furnaces are located during the inter-harvest period, and Figures 3A and B show the dynamics of the sector during the harvest period with the furnaces in operation.

3.1 Occupational Heat Assessment

At the unit evaluated, the drying process is carried out artificially with the use of dryers. Wood-burning furnaces are used, presenting hazards to the health of workers exposed to high temperatures that, depending on the exposure time, may lead to dehydration, with the most common heat-associated afflications being syncope and heat edema (Gouveia et al., 2013; Mota, 2015).

Temperature is considered an damaging factor, which is described in NR 15 - Unhealthy activities and operations, in its Annex No. 3 - tolerance limits for exposure to heat. This standard establishes the criteria for the characterization of an hazardous work environment resulting from exposure to heat in closed environments or environments with artificial sources, found in grain drying and storage units. The quantitative assessment of heat should be performed based on the methodology and procedures of NHO 06 (Fundacentro, 2017; SIT, 2019).

The occupational heat assessment was performed in the area with the highest exposure, the furnace sector, where control, monitoring, and feeding of the furnaces are performed during the harvest period; in the inter-harvest period, only maintenance and cleaning of the environment are performed.
Two measurements were performed: 11/28/2022 (inter-harvest period) and 02/23/2023 (harvest period), following the equipment stabilization procedures before starting the measurements.

On 11/28/2022 the weather conditions were: sunny; air temperature: 25 ºC; relative humidity: 62.29%; 02/23/2023 the weather conditions were: sunny between clouds, air temperature: 23.13 ºC and relative humidity: 87.54% (data obtained from the weather station of the Paraná Rural Development Institute - IAPAR).

In the inter-harvest period, it was observed that the worker is exposed to only one thermal condition, since the furnaces are turned off, obtaining an IBUTG of 23.5 ºC, metabolism rate of 279 w (moderate work with both arms). Figure 4 represents the behavior of the IBUTG, tbs, tbn and tg during the sampling period, confirming the stability of the variables.

![Figure 4: Inter-harvest period - IBUTG, tbs, tbn and tg temperature](image)

Source: Authors creation

The summary and result of the evaluation is shown in Table 2.

<table>
<thead>
<tr>
<th>Average Metabolism (w)</th>
<th>Total time sampled (hh:mm)</th>
<th>Average IBUTG (ºC)</th>
<th>IBUTG Action Level (ºC)</th>
<th>IBUTG Exposure Limit (ºC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>279</td>
<td>01:05</td>
<td>23.5</td>
<td>25.4</td>
<td>28.5</td>
</tr>
</tbody>
</table>

Table 2. Inter-harvest period: heat exposure assessment summary

Source: Authors creation

It is observed that the exposure conditions meet the requirements of the legislation and did not exceed the action level of 25.4 ºC and the occupational exposure limit of 28.5 ºC, considering the average IBUTG of 23.5 ºC acceptable for a metabolism rate of 279 W, with recommendation to at least maintain the current conditions.
During the harvest period, it was observed that the worker performs a work cycle every 15 min on average, which corresponds to a set of activities developed in a defined sequence and that is repeated continuously during the workday.

Each cycle is composed of two events. During the first 4 min (event 01) he feeds the wood stove, and in the remaining 11 min (event 02) he replaces the wood stock and monitors the system temperature. These activities were measured and observed during 60 min, completing 4 full cycles. It can be observed in Figure 5 the existence of temperature peaks, when the operator opens the furnace hatch to put firewood. In event 01 occurs the most unfavorable thermal condition with the furnace open, which was considered as work (metabolism of 279 w - moderate work with both arms) and event 02 as the rest period (metabolism of 180 w - moderate work with the hands). The results of the evaluations with the respective cycles, events, IBUTG, exposure time, and metabolism (watt) are presented in Table 3.

![Figure 5: Harvest period - IBUTG exposure cycle temperature, tbs, tbn and tg](source)

**Figure 5: Harvest period - IBUTG exposure cycle temperature, tbs, tbn and tg**

<table>
<thead>
<tr>
<th>Cicle</th>
<th>Event</th>
<th>IBUTG (ºC)</th>
<th>Exposure time: (hh:mm)</th>
<th>Metabolism (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>01</td>
<td>24.7</td>
<td>00:04</td>
<td>279</td>
</tr>
<tr>
<td></td>
<td>02</td>
<td>24.3</td>
<td>00:12</td>
<td>180</td>
</tr>
<tr>
<td>02</td>
<td>01</td>
<td>25.0</td>
<td>00:04</td>
<td>279</td>
</tr>
<tr>
<td></td>
<td>02</td>
<td>24.9</td>
<td>00:17</td>
<td>180</td>
</tr>
<tr>
<td>03</td>
<td>01</td>
<td>25.3</td>
<td>00:04</td>
<td>279</td>
</tr>
<tr>
<td></td>
<td>02</td>
<td>25.1</td>
<td>00:11</td>
<td>180</td>
</tr>
<tr>
<td>04</td>
<td>01</td>
<td>25.9</td>
<td>00:04</td>
<td>279</td>
</tr>
<tr>
<td></td>
<td>02</td>
<td>25.7</td>
<td>00:12</td>
<td>180</td>
</tr>
</tbody>
</table>

**Table 3. Harvest period: heat exposure cycle evaluation**

The summary and result of the evaluation is presented in Table 4, for the harvest period.
<table>
<thead>
<tr>
<th>Average Metabolism (w)</th>
<th>Total time sampled (hh:mm)</th>
<th>Average IBUTG (ºC)</th>
<th>IBUTG Action Level (ºC)</th>
<th>IBUTG Exposure Limit (ºC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>230</td>
<td>01:07</td>
<td>25.1</td>
<td>26.6</td>
<td>29.5</td>
</tr>
</tbody>
</table>

Table 4. Harvest period: heat exposure assessment summary
Source: Authors creation

Regarding the evaluation criteria, exposure conditions were complied and did not exceed the action level of 26.6 ºC and the occupational exposure limit of 29.5 ºC, considering acceptable the average IBUTG of 25.1 ºC for an average metabolism rate of 230 w, with recommendation to at least maintain the current conditions. By following the quantitative evaluations and inspecting the environment, Figure 6, the following scores were obtained during the harvest period.
A score of 70 (regular level) in good condition was attained, with restriction to the standard. According to the quantitative evaluation performed, it was observed that the average
IBUTG value was below the occupational exposure action level; the company supplies water and encourages its intake.

It is not possible to schedule heavier work in periods with milder thermal conditions, because the work during the harvest period is done on-demand. It is possible to alternate between operations that generate exposure at higher and lower levels, resulting in reduced exposure; the company has natural environments in the workplace with milder temperatures to take spontaneous breaks and the structure of the furnace itself is considered a barrier to radiant heat.

It is not necessary to have ventilation in the workplace, since it is an open environment with natural ventilation. The environment has no mechanisms to control the temperature, relative humidity and emissivity of the heat source when the furnace is being supplied with firewood.

The employee's activities are performed indoors. Currently the company provides all employees with a helmet (CA 29638) to protect the user's head against the impact of objects on the skull and against electric shock, hearing protection (CA 33835) to protect the user's auditory system against sound pressure levels higher than those established in NR 15, annexes I and II, according to the attenuation table of 17 dB(A), gloves (CA 29368) to protect the user's hands against abrasive, cutting, and perforating agents and against thermal agents (heat and flames), which had expired and could not be used, leather apron (CA 37009) to protect the user's torso against abrasive and thermal agents from welding operations and similar processes, and visor with face protection (CA 15019) to protect the user's eyes against impacts from frontal flying particles, consultation carried out in the system of the Ministry of Labor and Social Security - Approval Certificate of Personal Protective Equipment (CAEPI).

3.2 Occupational Noise Assessment

The presence of noise above 80 dB in the work environment can cause discomfort and, over time, impair hearing. This causes interference with communication and reduced concentration, which can occur with relatively low noise. A noise that exceeds the average of 80 dB (A) in eight hours of exposure can cause deafness and even accidents if the message transmitted is interpreted incorrectly (Dul & Weerdmeester, 2004; Gouveia et al., 2013; Dias et al., 2019; Nari et al., 2020).

Four measurements were performed for occupational noise evaluation, evaluations 1 and 2 on 11/28/2022, with summary of dosimetry presented in Table 5, beginning at 10:00
hours and ending at 11:18 hours (inter-harvest period) and evaluations 3 and 4 on 02/23/2023 with data recorded in Table 6, beginning at 9:35 hours and ending at 10:52 hours (harvest period), the equipment was calibrated before and at the end of the measurements.

<table>
<thead>
<tr>
<th>Evaluation 1</th>
<th>Evaluation 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dosimeter 1</td>
<td>Dosimeter 2</td>
</tr>
<tr>
<td>NEN: 57.6 dB (A)</td>
<td>76.6 dB (A)</td>
</tr>
<tr>
<td>LMAX: 89 dB (A)</td>
<td>103.4 dB (A)</td>
</tr>
<tr>
<td>DOSEp: 0.1%</td>
<td>14.3%</td>
</tr>
</tbody>
</table>

Table 5. Dosimetries performed during the inter-harvest period (11/28/2022)
Source: Authors creation

<table>
<thead>
<tr>
<th>Evaluation 3</th>
<th>Evaluation 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dosimeter 1</td>
<td>Dosimeter 2</td>
</tr>
<tr>
<td>NEN: 83.8 dB (A)</td>
<td>85 dB (A)</td>
</tr>
<tr>
<td>LMAX: 98.6 dB (A)</td>
<td>104.6 dB (A)</td>
</tr>
<tr>
<td>DOSEp: 75.7%</td>
<td>99.9%</td>
</tr>
</tbody>
</table>

Table 6. Dosimetries performed during the harvest period (02/23/2023)
Source: Authors creation

We can observe in evaluations 1 and 2, Table 5, that the Normalized Exposure Level - NEN, which represents the average noise level converted to an 8-hour day, used for comparison purposes with the tolerance limit of 85 dB(A), were below the criteria level when using the 3 dB doubling rate (NHO 01): 57.6 dB (A) and 76.6 dB (A); or 5 dB (NR 15): 39.5 dB (A) and 67.8 dB (A) during the inter harvest period. The same occurred during the harvest period, represented by evaluations 3 and 4, Table 6, doubling rates of 3 dB: 83.8 dB (A) and 85 dB (A); or 5 dB: from 80.5 dB (A) and 81.4 dB (A). This fact is ratified if we analyze the Projected Noise Dose - DOSEp, which represents the daily exposure to noise and cannot exceed the 100% unit, regardless of the length of the work day; the evaluations were below this threshold: inter-harvest period with 0.1%, 0.1%, 14.3% and 9.2%, and during the harvest period with 75.7%, 53.5%, 99.9% and 60.7%.

In the inter-harvest period the action level was not extrapolated, daily dose below 50%; when the daily dose is between 50-100% the exposure is considered above the action level, observed in the evaluations carried out in the harvest period (Fundacentro, 2001).

When the daily dose (%) is between 50 and 80, the technical consideration is that it is above the action level and the adoption of preventive measures is recommended, which was observed in three evaluations carried out during the harvest period, and if the daily dose is between 80 and 100, one evaluation obtained this result, the technical consideration describes a region of uncertainty in which the adoption of preventive and corrective measures is
recommended with the objective of reducing the daily dose, which aims to protect the worker's hearing and prevent the exposure limit from being exceeded (Fundacentro, 2001).

LMAX, Tables 5 and 6, represents the highest sound pressure level during the evaluation, inter-harvest period: evaluation 1: 89 dB (A) and evaluation 2: 103.4 dB (A). During the harvest period: assessment 3: 98.6 dB(A) and assessment 4: 104.6 dB(A). At no time during the work day were the continuous or intermittent noise levels above 115 dB (A), which would not be allowed for individuals who were not adequately protected (Fundacentro, 2001; SIT, 2019).

After performing the quantitative assessments, we inspected the environment, illustrated in Figure 7, which represents the worst situation of noise exposure, assessment 4, which generated a score of 90.

Of the 104 possible points, the company scored 90 (normal level) in good condition with few restrictions to the standard, for not being able to keep the work environment with a NEN below 80 dB (A) for 8 hours of daily exposure, which represents the action level for occupational noise exposure, question 01, since the obtained value of 85 dB (A) NHO 1 or 81.4 dB (A) NR15, are intrinsic to the production process.

The employee's activities are performed in the operational sector in internal and external environments. Currently the company provides all employees with a helmet and hearing protection (CA 33835), which according to consultation with the CAEPI system, the CA is valid and has a degree of attenuation of 17 dB (A), exposing the hearing aid of the worker (85 - 17 = 68) to 68 dB (A).

Regarding the inspection of the PPE's used, the environment has a sign describing the mandatory use, they were recommended by a qualified occupational safety technician who made the record of delivery, training and performs periodic inspections. In the operational sector the employees have a place to store and clean the PPE's, and the company does not have complementary protection devices.

Through the analysis of 22 dosimetrys performed in the years 2020 to 2022 in grain receiving and storage units, data provided by a company that provides consulting services in the area of labor safety engineering in the western region of Paraná, it was observed that the action level for the NEN was extrapolated in 11 situations, with an average noise of 85.83 dB (A), close to the result obtained in this research.
### Figure 7: Unit sound intensity inspection worksheet - assessment #4 - 02/23/2023

Source: Authors creation
In the grain receiving units, noise is present in practically the entire process, from the arrival of the product to storage, being many times above the tolerance limit established by legislation, especially during the harvest period. In a study carried out in the machine room of a unit in the city of Maringá - PR, it was verified that the noise levels obtained were above the tolerance limit established by NR 15, where it was identified that the main sources of noise were found in the pre-cleaning and cleaning machine, the dryer and the unloading of grains in the hopper. As the workers used PPE, the noise was attenuated to levels acceptable by legislation not offering hazard to workers (Gasques et al., 2018; Dias et al., 2019).

These results show the high incidence of noise in the activities performed, which justifies the importance of developing research that focuses on improving environmental working conditions.

Action plan:

Among the hazards evaluated it can be observed that occupational exposure to heat obtained the lowest score (70) when compared to exposure to noise (90). Using the proposed methodology, the resolution of non-conformities regarding heat exposure should be prioritized, with the following suggestions:

1. Immediate replacement of the gloves (CA 29368) that have expired approval certificates, not providing the correct protection of the user's hands against abrasive, cutting and perforating agents and against thermal agents (heat and flames);
2. Install a temperature and humidity gauge in the environment;
3. To have a reflective barrier in the workplace to protect the worker from the emissivity of the heat source when the furnace is being supplied with firewood.

Making the adjustments, the score would go from the current 70 to 104, in good condition with no restrictions to the standard.

In occupational noise exposure, it is observed the need to reduce the ambient noise intensity that has exceeded the action level, with a NEN above 80 dB (A) for 8 hours/day. This occurs because environmental noise is intrinsic to the production process (truck circulation, loading, unloading, engines, among other sources). It is recommended to use air conditioner in the existing break room, so that the doors and windows can be kept closed, which would significantly reduce the noise in this place during breaks and administrative work. Such an adjustment could increase the score from the current 90 to 104, in good condition with no restrictions to the standard.

The action plan was presented to the company's SESMT, which validated the methodology presented. It is intended to develop software for collecting and information...
recording non-conformities identified for all hazards intrinsic to the process, which will help the company to maintain an updated database and assertively deploy efforts in prioritizing and solving problems, whether for single units or the set of units.

Hazard management helps decision-making, considering uncertainties and the probability of certain situations or future events, intended or unintended, and their effects through a methodology of identification, analysis, and hazard assessment as presented in this research (Issa et al., 2018; ABNT, 2020; Asongu et al., 2022;).

Conclusions

The hazard management methodology proved to be effective for the analysis, identification, evaluation (quantitative and qualitative), prioritization and preparation of the action plan. Through the scoring system the company is able to prioritize the situations that indicate a higher hazard of accident/illness.

The application of this methodology will create a database, which allied to artificial intelligence, can help to identify and predict situations of hazard in the work environment, with the development of the software. Compliance with the legislation which reduces fines and interdictions of the process, and lack of standardized norms among countries.

Acknowledgements

This article was supported by the Business University Innovation Program (Itaipu Technological Park - PTI), the company APTA Safety at work, Federal University of Technology of Paraná (UTFPR) and the Western Paraná State University (UNIOESTE).

References


FUNDACENTRO - Jorge Duprad Figueiredo Foundation for Occupational Safety and


IBGE - Instituto Brasileiro de Geografia e Estatística. (2023a). Agricultural storage capacity grows 3.0% and reaches 188.8 million tons in the 1st half of 2022 - Agência de Notícias. Available in: <https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/35416-capacidade-de-armazenagem-agricola-crece-3-0-e-chega-a-188-8-milhoes-de-toneladas-no-1-semester-de-2022> (Br).

IBGE - Instituto Brasileiro de Geografia e Estatística. (2022b). Agricultural storage capacity grows 1.5% and reaches 183.3 million tons in the 2nd half of 2021. Available at: <https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/33996-capacidade-de-armazenagem-agricola-crece-1-5-e-chega-a-183-3-milhoes-de-toneladas-no-2-semester-de-2021> (Br).


Revista Gestão e Secretariado (GeSec), São Paulo, SP, v. 14, n. 12, 2023, p. 21599-21624.
Life, 10 (1), 46.


Submetido em: 10.11.2023
Aceito em: 15.12.2023