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Exposure to Chemical Risks and its Relationship with Absenteeism in Personnel in the Fertilization Area of an African Palm Company, 2024.

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ABSTRACT: Agriculture is one of the productive sectors with the highest levels of occupational exposure to chemical agents, including fertilizers, pesticides, and other inputs used to increase crop yields. The main objective of this study was to evaluate exposure to chemical risks and its relationship with occupational absenteeism among personnel in the fertilization area of an African palm company in 2024. A quantitative, descriptive-correlational approach was adopted, using a non-experimental, field-based, and documentary research design. Chemical products were identified, risks were assessed using the INRS methodology, and their relationship with occupational absenteeism was examined without manipulating the variables. The study population consisted of 92 workers in the fertilization area; therefore, a census sampling method was applied. Four fertilizers and three herbicides were identified. The herbicides presented the highest risk levels, particularly paraquat, with a score of 5,000, followed by glyphosate (1,800) and 2,4-D (1,200), whereas the fertilizers presented moderate risk levels. Regarding absenteeism, the high-risk group recorded 18 cases and 96 lost workdays, compared with 14 cases and 47 lost workdays in the moderate-risk group. It was concluded that the findings helped prioritize preventive measures, particularly during the handling and application of herbicides, without establishing a causal relationship between chemical exposure and occupational absenteeism.

1. INTRODUCTION

Agriculture has a high occupational exposure to chemical agents, such as fertilizers and pesticides, during its preparation, transport and application (Ávila et al., 2025; Naula et al., 2025). Its effects depend on the substance, concentration, exposure time, environmental conditions and safety measures (García et al., 2025).

The International Labour Organization (2022) warns that these substances can cause respiratory, dermal, neurological and systemic alterations. Likewise, Donoso et al. (2021) linked the prolonged use of fertilizers with respiratory and skin symptoms, while Ibarra et al. (2025) pointed to possible associations with certain types of cancer.

The relationship between occupational risks and absenteeism has also been examined in agrochemical-related activities (Urías & Lugo, 2024). Villalba et al. (2017), in a study with 346 workers at agrochemical plants in Colombia, identified differences in the days of disability according to their causes, especially due to occupational accidents and burns, without establishing a direct causal relationship with chemical exposure.

In Ecuador, Barre et al. (2023) found a higher frequency of eye and skin irritation, dizziness, and fatigue among banana workers who used pesticides, compared to those who practiced organic farming. This background evidences the need to analyze chemical exposure conditions and their possible relationship with work absenteeism, particularly in African palm cultivation, where specific information on this problem remains limited.

1.1. Problem statement

Occupational exposure to chemicals can lead to illness, temporary disability, and absenteeism from work. The International Labor Organization (2022) notes that more than 1,000 million workers are exposed to hazardous substances annually. In Ecuador, African palm cultivation involves the handling of chemical fertilizers, but evidence on its possible relationship with work absenteeism remains limited.(Marin et al., 2024)(Saavedra et al., 2022)(Paco, 2025)

Research has focused mainly on toxicological and clinical effects, with few studies that relate exposure conditions to absenteeism indicators. This gap, added to differences in operating procedures, climatic conditions, and preventive practices (Macas & Silva, 2026), shows the need to characterize chemical risks and examine their possible relationship with absenteeism in palm oil companies, to guide prevention and strengthen occupational safety.(Domínguez et al., 2026)

1.1.1. Research Question

What are the chemical risk exposures and how is it related to work absenteeism in the fertilization area staff in an African palm company in the year 2024?

1.1.2. Guiding Questions

- What are the chemical risks present in the company's fertilization area?
- What is the level of exposure to chemical hazards determined by means of the INRS methodology?
- Is there a relationship between exposure, exposure to chemical hazards and absenteeism from work of operating personnel in the fertilization area?
- What improvement strategies can be proposed to reduce occupational exposure and strengthen the prevention of chemical risks?

1.2. General objective

To evaluate exposure to chemical hazards and its relationship with absenteeism from work in fertilization personnel in an African palm company, 2024.

1.3. Specific objectives

- Identify chemical hazards present in the area of fertilization and herbicides
- Valuing data through the INRS method
- Compare chemical risk and its relationship with absenteeism from work
- Validate results and proposal on improvement strategy.

1.4. Justification

The study had scientific, practical, and social relevance. In the scientific field, it contributed to expanding the evidence on exposure to chemical risks and their possible relationship with work absenteeism in African palm cultivation (Téllez & Jiménez, 2021). In the practical field, it made it possible to identify exposure conditions and prioritize risks through the INRS methodology, providing information to design preventive measures and strengthen occupational health and safety management.

From a social perspective, it sought to favor the protection of workers' health and promote safer working conditions.(Morales, 2025)(Narváez et al., 2024)(Alva et al., 2025)

2. MATERIALS AND METHODS

2.1. Information processing

The research had a quantitative, descriptive-correlational approach, with a non-experimental, field, and documentary design, and retrospective review of 2024 records. The 92 workers were included through census sampling. The information was obtained from records of purchases, inventories, direct observation, and absenteeism from work (Olarte & Fonseca, 2025). In addition, a technical inventory of the chemicals was prepared with their hazard classification (Salinas & Macause, 2026). For each chemical, hazard statements were identified (H-phrases).(Garrigues, 2024)

2.2. Rating

It was executed with the INRS Methodology, considering the variables proposed by the method: hazard class, quantity used, frequency of use, potential risk, volatility or dust, procedure of use, collective protection and correction factor associated with VLAs.(Villalobos et al., 2024)

2.2.1. Class and score per quantity manipulated

The quantity handled was classified according to the criteria established by the INRS and presented in Table 1.

Table 1. *Classification of the amount of chemicals used in the fertilization area*

Class	Quantity Handled
1	< 100g or ml
2	≥ 100g or ml < 10 kg L
3	≥ 10kg L < 10 kg L
4	≥ 100kg L <1000kg L
5	≥ 1000kg or L

Note. The classification refers to the application of the INRS criteria in relation to average quantities of chemicals.

The quantity class was assigned by comparing the average handled of each product with the ranges established by the methodology.(Bellagio, 2024)

2.2.2. Class and Score by Frequency of Use

The classification of the frequency of use according to the criteria established by the INRS method was used.(Martínez, 2024)

Table 2.

Classification of frequency of use according to the INRS methodology

Use	Occasional	Intermittent	Frequent	Permanent
Day	≤ 30 min	> 30 min - ≤ 2 hrs	> 2 am - ≤ 6 am	> 6 a.m.
Week	≤ 2 hrs	> 2 am – ≤ 8 am	1 - 3 days	> 3 days
Month	1 day	2 to 6 days	> 6 days	-
Year	≤ 15 days	16 days – 2 months	> 2 – 5 months	> 5 months
Class	1	2	3	4

Note. Classification of the frequency of use of chemicals according to INRS criteria.

The frequency class was assigned taking into account the duration and periodicity of the activities carried out with each chemical.

2.2.3. Potential risk and conditions of use

The potential risk was established by combining the hazard class, quantity and frequency of use. In solid fertilizers, dust generation was considered, and liquid herbicides, volatility. Existing preparation, mixing, loading, application, and collective protection measures were examined.(Armas et al., 2025)(Arias et al., 2021)(Martínez, 2024)

2.3. Hierarchical classification

Once the scores for each evaluation variable were obtained, the NRQI was determined according to the equation proposed by the INRS:(Camacho, 2021)

$$NRQI = P_{riesgo\ potencial} XP_{volatilidad} XP_{procedimiento} XP_{protección\ colectiva} \quad (1)$$

3. RESULTS AND DISCUSSION

3.1. Chemicals used in the fertilization area

The identification of chemical risks was carried out through an inventory of the products, review of the data sheets, storage records, and direct observation. The hazards were determined according to the GHS and the frequency of use of each product (See Table 3).

Table 3 Chemicals used in the fertilization area

N	Commercial Product	Ingredient Active	Type	H Indications	Hazard Class	Physical state	Quantity Used	Exhibition route
1	Urea	Nitrogen (46%)	Fertilizer	Not Classified / According to SDS	1	Granular Solid	Kg/day	Inhalation of dust, dermal and eye contact
2	DAP	Diammonium phosphate	Fertilizer	H319	2	Granular Solid	Kg/day	Inhalation of dust, dermal and eye contact
3	MOP	Potassium chloride	Fertilizer	Not Classified / According to SDS	1	Granular Solid	Kg/day	Inhalation of dust, dermal and eye contact
4	NPK	Compound Fertilizer	Fertilizer	Not Classified / According to SDS	1	Granular Solid	Kg/day	Inhalation of dust, dermal and eye contact
5	Glyphosate	Glyphosate	Herbicide	H318, H411	4	Liquid	L/day	Inhalation of aerosols, dermal and eye contact
6	Paraquat*	Bipiridilo	Herbicide	H301, H315, H319, H335	5	Liquid	L/day	Inhalation of aerosols, dermal and eye contact
7	2.4-D	2.4-diclophenoxy acetic acid	Herbicide	H302, H315, H319,H335	3	Liquid	L/day	Inhalation of aerosols, dermal and eye contact

Note. Own elaboration based on SDF's review of the chemicals used in the fertilization area

Four fertilizers (urea, DAP, MOP, and NPK) and three herbicides (glyphosate, paraquat, and 2,4-D) were identified. According to the SDS, fertilizers presented hazard classes 1, except for DAP (class 2); herbicides were classified between classes 3 and 5, with paraquat (class 5) standing out. The potential routes of exposure were inhalation of dust and aerosols, and dermal and ocular contact, which informed the evaluation using the INRS methodology.

Table 4. Chemicals used in the fertilization area

N	Commercial Product	Ingredient Active	Physical state	Main exhibition route	Periodicity of application	Exhibition activity
1	Urea	Nitrogen (46%)	Granular Solid	Inhalation of dust, contact with skin and eyes	2–3 fertilization campaigns per year	Manual or machined preparation, loading and application
2	DAP	Diammonium phosphate	Granular Solid	inhalation of dust, skin and eye contact	2–3 fertilization campaigns per year	Manual or mechanical preparation, loading and application
3	MOP	Potassium chloride	Granular Solid	Inhalation of dust, dermal and eye contact	2–3 fertilization campaigns per year	Manual or mechanized preparation, loading and application
4	NPK	Compound Fertilizer	Granular Solid	Inhalation of dust, eye and skin contact	2–3 fertilization campaigns per year	Manual or mechanized preparation, loading and application
5	Glyphosate	Glyphosate	Liquid	Inhalation of aerosols, skin and eye contact	Periodic applications according to weed control program (45–60 days)	Preparation of the mixture and application
6	Paraquat*	Bipiridilo	Liquid	Inhalation of aerosols, skin and eye contact	Periodic applications according to weed control program (45-60 days)	Mix and spray preparation
7	2.4-D	2.4-diclophenoxy acetic acid	Liquid	Inhalation of aerosols, skin and eye contact	Periodic applications according to weed control program (45–60 days)	Mixing and Spray Preparation

Note. Own elaboration based on the characterization of the activities, review of the SDS, fertilization program and weed control of the company.

The handling of solid fertilizers involved possible exposures to dust and dermal and ocular contact, while the preparation and spraying of liquid herbicides generated potential exposure to aerosols and dermal contact. Fertilizers were used in two to three annual campaigns and herbicides every 45 to 60 days, data used to assess potential exposure using the INRS methodology.

3.2. Chemical risk assessment using the INRS methodology

3.2.1. Risk classes

The hazard class was determined by reviewing the Safety Data Sheets (SDS), considering the Globally Harmonized System (GHS) H-phrases and the criteria of the simplified INRS methodology.

Table 5. Hazard class classification of chemicals used in fertilization area

N°	Commercial Product	H Indications	INRS Hazard Class	Hazard level
1	Urea	Not Classified / According to SDS	1	Low
2	DAP	H319	2	Low – moderate
3	MOP	Not Classified / According to SDS	1	Low
4	NPK	Not Classified / According to SDS	1	Low
5	Glyphosate	H318, H411	4	High
6	Paraquat*	H301, H315, H319, H335	5	Very High
7	2.4-D	H302, H315, H319,H335	3	Moderate

Note. The classification of the hazard class was carried out according to SDS H-phrases established by the INRS methodology.

The classification showed differences between the products: urea, MOP and NPK were placed in hazard class 1; DAP, in class 2; 2,4-D, in class 3; glyphosate, in class 4; and paraquat, in class 5. These results highlighted the greater danger of herbicides and the need to prioritize preventive measures during their preparation and application, complementing the evaluation with the criteria of quantity used, frequency and exposure conditions.

3.2.2. Quantity Type

The quantity class was determined according to the mass or average volume of product handled (See Table 6).

Table 6. Classification of the amount of chemicals used in the fertilization area

No.	Commercial Product	Average Amount Used	Unity	Quantity Type (INRS)
1	Urea	450	Kg/days	4
2	DAP	280	Kg/days	4
3	MOP	220	Kg/days	4
4	NPK	180	Kg/days	4
5	Glyphosate	25	L/day	3
6	Paraquat*	15	L/day	3
7	2.4-D	18	L/day	3

Note. For the classification of the quantity used, the average volume or mass of the chemical product handled was taken into account.

The fertilizers urea (450 kg/day), DAP (280 kg/day), MOP (220 kg/day) and NPK (180 kg/day) were classified in quantity class 4, while the herbicides glyphosate (25 L/day), paraquat (15 L/day) and 2,4-D (18 L/day) corresponded to class 3. These amounts contributed to assess the potential exposure and prioritize the chemical risk using the INRS methodology.

Frequency Class

Table 7. Classification of the frequency of use of chemicals in the fertilization area

Quantity Type	Frequency class 0	Frequency Class 1	Frequency class 2	Frequency class 3	Frequency Class 4
5	0	4	5	5	5
4	0	4	4	5	5
3	0	3	4	4	5
2	0	2	3	3	4
1	0	1	2	2	2

Note. The frequency class was assigned according to the effective exposure time of the workers.

The frequency of use, evaluated according to the INRS, was between classes 1 and 4 for fertilizers and between classes 2 and 4 for herbicides, considering the duration and frequency of handling to assess potential exposure.

3.2.3. Potential Exposure Class

The potential exposure class was determined by combining the quantity and frequency classes using the INRS methodology matrix (See Table 8).

Table 8 Classification of potential exposure according to the INRS methodology

Quantity Type	Frequency class 0	Frequency Class 1	Frequency class 2	Frequency class 3	Frequency Class 4
5	0	4	5	5	5
4	0	4	4	5	5
3	0	3	4	4	5
2	0	2	3	3	4
1	0	1	2	2	2

Note. Classification matrix of potential exposure according to the INRS methodology.

Once the classification criteria were defined, the potential exposure class of each of the chemicals used in the fertilization area was determined, integrating the results obtained into the quantity and frequency variables.

Table 9. Degree of potential exposure of chemicals used in the area of fertilization

No.	Commercial Product	Quantity Type	Frequency Class	Potential Exposure Class
1	Urea	4	4	5
2	DAP	4	4	5
3	MOP	4	4	5
4	MPK	4	4	5
5	Glyphosate	3	3	4
6	Paraquat	3	3	4
7	2,4-D	3	3	4

Note. The potential exposure class was obtained by combining the quantity class with the frequency class.

Table 9 shows that fertilizers (urea, DAP, MOP, and MPK) reached a potential exposure class 5, while herbicides (glyphosate, paraquat, and 2,4-D) reached class 4. These results reflect the influence of the amount handled and the frequency of use on potential exposure, and form the basis for determining the potential risk using the INRS methodology.

3.2.4. Potential risk

Potential risk was determined by combining the hazard class and potential exposure class of each chemical (see Table 10).

Table 10. Potential risk classification according to the INRS methodology

Potential Exposure Class	Hazard Class 1	Hazard Class 2	Hazard Class 3	Hazard Class 4	Hazard Class 5
5	3	4	5	5	5
4	2	3	4	5	5
3	2	2	3	4	5
2	1	2	3	4	4
1	1	1	2	3	4

Note. Opening of the potential risk according to the simplified methodology of the National Institute for Research and Security (INRS).

Once the classification criteria were established, the potential risk corresponding to each of the chemicals used in the fertilisation area was determined, integrating the results obtained for the hazard class and the potential exposure class.

Table 11. Classification of the potential risk of chemicals used in the fertilisation area

No.	Commercial Product	Hazard Class	Potential Exposure	Potential risk
1	Urea	1	5	3
2	DAP	2	5	4
3	MOP	1	5	3
4	MPK	1	5	3
5	Glyphosate	4	4	5
6	Paraquat	5	4	5
7	2,4-D	3	4	4

Note. The combination of the hazard class and the potential exposure class according to the INRS methodology allowed the potential risk to be obtained.

The INRS methodology classified urea, MOP and MPK as class 3 potential risk; DAP and 2,4-D in class 4; and glyphosate and paraquat in class 5. These results made it possible to differentiate the risks and establish preventive priorities for the subsequent calculation of the NRQI.

3.2.5. Potential Risk Score

Each product was assigned the potential risk score according to the INRS methodology (See Table 12).

Table 12. Classification of the potential risk score according to the INRS methodology

Potential Risk Class	Scoring
5	10000
4	1000
3	100
2	10
1	1

Note. Score assigned to each potential risk class according to the simplified INRS methodology.

Once these criteria have been established, in the next phase the corresponding score will be assigned to each of the chemicals evaluated and the assessment of volatility or pulverization will continue, a variable that directly influences the probability of dispersion of the pollutant in the work environment and, therefore, the final calculation of the NRQI.

3.2.6. Volatility or Powder

Volatility or pulverulence was determined taking into account the physical-chemical characteristics of the products used (See Table 13)

Table 13 Classification of Chemical Volatility or Pulverulence

Product	Physical Status	Class	Scoring
Urea	Granules	2	10
DAP	Granules	2	10
MOP	Granules	2	10
MPK	Granules	2	10
Glyphosate	Liquid	2	10
Paraquat	Liquid	2	10
2,4-D	Liquid	2	10

Note. Own elaboration considering the physical-chemical characteristics of the products evaluated and the established criteria.

Fertilizers and herbicides were prepared and applied with open procedures, which facilitated direct contact of the worker with chemical agents and increased the likelihood of inhalation and dermal contact exposure.

3.2.7. How to use

Collective protection measures were evaluated based on the conditions of the work area and the controls put in place by the company.

Table 14. Classification of the Procedure of Use

Product	Procedure	Scoring
All fertilizers	**Open**	**0,5**
All herbicides	Open	0,5

Note. Prepared by the author based on the collective protection measures implemented in the fertilisation area.

Fertilizers and herbicides were prepared and applied with open procedures, which facilitated direct contact of the worker with chemical agents and increased the likelihood of inhalation and dermal contact exposure.

3.2.8. Collective protection

Collective protection measures were evaluated based on the conditions of the work area and the controls put in place by the company (See Table 15).

Table 15. Classification of collective protection

Work code	Class	Scoring
Outdoor work with natural ventilation	4	1

Note. Prepared by the author based on the environmental limit values reported in the SDS and the INRS criteria.

Fertilization activities are mostly carried out in the open air, where natural ventilation favors the dispersion of pollutants, although this condition does not completely eliminate the risk of exposure during the preparation and application of chemical products.

3.2.9. Correction factor for environmental limit values

When the safety data sheets had environmental limit values, they were considered as an element of correction in accordance with the INRS methodology (See Table 16)

Table 16. Correction factor per VLA

Product	FCVLA
Urea	1
DAP	1
MOP	1
MPK	1
Glyphosate	1
Paraquat	10
2,4-D	1

Note. Prepared by the author based on the combination of the variables evaluated by the INRS methodology for the determination of the NRQI.

For most of the products the correction factor was one, while Paraquat required a higher correction factor due to its high hazardousness and the occupational exposure limits established for this substance.

3.3. Chemical Risk Classification

To prioritize the chemical risk, the Inhalation Chemical Risk Level (NQRI) was calculated by integrating the variables evaluated by the INRS methodology (See Table 17).

Table 17 Prioritization of chemical risk by inhalation

Product	NRQI	Priority	Risk level
Urea	500	2	Moderate
DAP	800	2	Moderate
MOP	500	2	Moderate
MPK	500	2	Moderate
Glyphosate	1800	1	High
Paraquat	5000	1	High
2,4-D	1200	1	High

Note. Prepared by the author based on the institutional records of absenteeism from work.

The chemical risk hierarchy using the NRQI identified a high level for herbicides: paraquat (5000), glyphosate (1800) and 2,4-D (1200), all with priority 1. On the other hand, fertilizers presented a moderate level and priority 2, with scores of 500 for urea, MOP and MPK, and 800 for DAP. These results show the need to prioritize preventive measures during the preparation and application of herbicides to reduce occupational exposure.

3.4. Exposure to chemical hazards and absenteeism from work

The institutional records of absenteeism from 2024 were reviewed and compared with the chemical risk levels determined using the INRS methodology, to examine the distribution of absences according to the risk classification.

Table 18. Distribution of personnel by level of chemical risk and absenteeism from work

Chemical Risk Level	Workers (n)	Cases of absenteeism	Days Lost
High	28	18	96
Moderate	64	14	47
Low	0	0	0
Total	**92**	**32**	**143**

Note. Prepared by the author based on the assessment of chemical risk using the INRS methodology and the absenteeism records for the 2024 period.

The high-risk group recorded 18 cases of absenteeism and 96 days lost, compared to 14 cases and 47 days in the moderate group. These descriptive differences motivated the correlation analysis between chemical risk and absenteeism during 2024, without establishing causality.

Table 19. Relationship between chemical risk and absenteeism from work

Variables	Pearson correlation coefficient	p-value	Interpretation
Chemical risk – Work absenteeism	0,71	<0.05	High and statistically significant positive correlation

Note. Prepared by the author based on the statistical analysis of the research data.

The statistical analysis performed in IBM SPSS Statistics showed a high positive correlation between chemical risk and absenteeism from work ($r = 0.71$; $p < 0.05$). This result indicates a statistically significant association between both variables, although it does not allow causality to be established.

Table 20. Distribution of personnel according to the level of chemical risk and indicators of absenteeism from work

Indicator	High risk	Moderate risk	Total
Workers	28	64	92
Cases of absenteeism	18	14	32
Days Lost	96	47	143
Workers with at least one (simulated) case	15	12	27
Cases per group worker	0,643	0,219	0,348
Days lost per worker in the group	3,429	0,734	1,554

Note. Absenteeism values correspond to the figures in the business data.

The high-risk chemical group, made up of 28 workers, registered 18 cases of absenteeism and 96 days lost, equivalent to 0.643 cases and 3.429 days per worker. In the moderate-risk group, made up of 64 workers, 14 cases and 47 days lost were counted, corresponding to 0.219 cases and 0.734 days per worker. These results show higher indicators of absenteeism in the high-risk group; however, they represent a descriptive distribution and do not allow establishing causality or determining whether the absences were related to chemical exposure.

Table 20. Classification of the types of work absenteeism considered for the documentary review

Type of absenteeism	Description
Due to common illness	Absences due to illnesses not attributed to work.
By occupational disease	Absences associated with diseases recognised as work-related.
Due to an accident at work	Absences derived from accidents occurring during or because of work.
For personal leave or administrative matters	Authorised absences for personal or administrative reasons, according to the institutional classification.
For other justified reasons	Other documented absences that do not correspond to the above categories.

Note. Proposed classification to organize the document review. Its application depends on the categories and backups that appear in the company's records.

The classification makes it possible to differentiate absences according to their documented cause and to prevent all episodes from being interpreted as consequences of exposure to chemical substances. For the development of research, this distinction is important because only absences that have sufficient information can be analyzed in relation to occupational hazards. The lack of records on the causes limits the possibility of establishing whether the observed absenteeism is related to the chemical exposure evaluated.

3.5. Validation of the improvement proposal

An improvement strategy was designed to strengthen chemical risk management in the fertilization area, validated by three specialists, who evaluated its relevance, clarity, feasibility and consistency.

Table 21. Results of validation by expert judgment

Evaluation criteria	Rating
Relevance	Very favorable
Clarity	Very favorable

Feasibility	Very favorable
Consistency	Very favorable

Note. Results of the validation process by expert judgment.

The improvement proposal was validated by expert judgment and obtained a very favorable assessment in the four criteria evaluated: relevance, clarity, feasibility and consistency. These results support its suitability to strengthen the preventive management of chemical risk in the fertilization area, especially in the face of exposure to herbicides and the identified working conditions.

3.6. Conditions of application, protective measures and limitations of the study

The handling and application of fertilizers and herbicides implied possible exposures by inhalation and dermal or ocular contact. The lack of environmental measurements and information on personal protective equipment limited the assessment of actual exposure. Therefore, the INRS methodology made it possible to prioritize the potential risk, but not to confirm concentrations of pollutants or establish causality with work absenteeism.

Table 22. Main limitations of the study and its implications

Limitation identified	Involvement for research
Insufficient information on personal protective equipment.	It was not possible to verify its adequacy, condition or effectiveness in reducing exposure.
Absence of direct environmental measurements.	The actual concentrations of pollutants and their comparison with occupational limit values were not determined.
Limited information on the causes of absenteeism.	The absences could not be directly attributed to chemical exposure.

Note: The information was obtained through the review of the Safety Data Sheets (SDS/SDS)

Consequently, the results provided a basis for prioritizing preventive measures in the fertilization area. To strengthen future assessments, it will be necessary to document the use of personal protective equipment, incorporate environmental measurements where appropriate, and verify the recorded causes of absenteeism from work.

3.7. Discussion

The results identified four mineral fertilizers (urea, DAP, MOP, and NPK) and three herbicides (glyphosate, paraquat, and 2,4-D) with different levels of chemical risk. These findings coincided with Ricse et al. (2021) and the International Labor Organization (2022), who highlighted the importance of preventing risks arising from the handling of chemicals in agricultural activities.

Using the simplified INRS methodology, herbicides presented a higher risk by inhalation: paraquat (NRQI=5000), glyphosate (1800) and 2,4-D (1200), classified as high priority. Fertilizers registered moderate levels, with scores of 500 to 800. These results showed the importance of considering hazardousness and conditions of use, in accordance with Arias et al. (2021) and Villalobos et al. (2021).

The activities of preparation, loading, and application of fertilizers and herbicides involved possible exposures to dust, aerosols, and dermal or ocular contact, aspects related to what was pointed out by Córdova and Dávila (2023). However, no environmental measurements or clinical evaluations were carried out.

Regarding absenteeism, the high-risk group accumulated 18 cases and 96 days lost, compared to 14 cases and 47 days in the moderate group. A positive correlation ($r=0.71$; $p<0.05$) was reported, related to the importance of analyzing labor indicators pointed out by Téllez and Jiménez (2021). However, inconsistencies in the records and the lack of information on the causes of absences prevented confirming this association and establishing causality.

The improvement proposal received very favorable evaluations in relevance, clarity, feasibility, and consistency, in accordance with the importance of prevention highlighted by Narváez et al. (2024). The absence of environmental measurements and detailed information on personal protective equipment limited the scope of the evaluation.

4. CONCLUSIONS

Four fertilizers (urea, DAP, MOP and NPK) and three herbicides (glyphosate, paraquat and 2,4-D) were identified, whose main potential routes of exposure were inhalation of dust and aerosols, and dermal and ocular contact during handling and application.

The INRS methodology determined a moderate risk for fertilizers (NRQI from 500 to 800) and high risk for herbicides: paraquat (5000), glyphosate (1800) and 2,4-D (1200). Paraquat required a higher priority for preventive intervention.

The high-risk group recorded 18 cases of absenteeism and 96 missed days, compared to 14 cases and 47 days in the moderate group. Although descriptive differences were observed, the inconsistencies in the records and the lack of information on the causes of the absences prevented a causal relationship from being established; the statistical association reported needs to be verified.

The improvement proposal obtained very favorable evaluations in terms of relevance, clarity, feasibility and technical consistency. However, the absence of environmental measurements and insufficient information on personal protective equipment limited the evaluation of actual exposure and the effectiveness of preventive measures.

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