International Journal of Innovative Research and Scientific Studies, 9(4) 2026, pages: 27-39

IJIRSS
International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Diagnosis of occupational health risks of peasant women exposed to agrochemicals in potato crops in southern Colombia

Diana Milena Muñoz Solarte[1*], Frixon Alexander Palma Perenguez[2], Victor Manuel Patiño Macias[3], Nataly Alexandra Orozco Certuche[4]

[1,2,3,4]*Autonomous University Corporation of Cauca, Environmental Research and Management Group (SIGAM), Faculty of Engineering, Technology and Environment, Popayán, Colombia.*

Corresponding author: Diana Milena Muñoz Solarte (*Email: diana.munoz.s@uniautonoma.edu.co*)

Abstract

This study assessed occupational health risks among peasant women exposed to agrochemicals in potato crops in the Gabriel López township (Cauca, Colombia). A mixed-methods approach was applied, involving 80 women from four rural communities. Data were collected through surveys, interviews, and narratives to characterize sociodemographic conditions, health history, and risk perception. Quantitative assessment was conducted using the Colombian Technical Guide GTC 45, identifying hazards and classifying risks into physical, chemical, biological, psychosocial, biomechanical, and natural categories. Results revealed risk levels ranging from low to critical, with chemical risk being the most significant. Agrochemical handling activities reached unacceptable risk levels (Levels I and II), with the highest criticality observed in Calvache. High vulnerability was identified due to prolonged exposure, limited use of personal protective equipment, and low educational levels. Reported health effects included renal and dermatological disorders, as well as potential reproductive impacts, in addition to risks related to solar radiation, ergonomic strain, and psychosocial stress. It is concluded that occupational risks are significant and strongly associated with unsafe agrochemical practices. The implementation of protective measures, training programs, occupational health surveillance, and sustainable agricultural practices is essential to reduce exposure and improve working and environmental conditions.

Keywords: Agrochemicals, Characterize, Critical risk, Emphasis, Occupational risks.

DOI: 10.53894/ijirss.v9i4.11444
Funding: This research was funded by the internal call for research projects and young researchers of the Autonomous University Corporation of Cauca.
History: Received: 20 January 2026 / **Revised:** 5 March 2026 / **Accepted:** 10 March 2026 / **Published:** 3 April 2026

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Institutional Review Board Statement: This study was conducted in accordance with international ethical principles for research involving human subjects, including the Declaration of Helsinki, as well as current national regulations in Colombia. The participation of peasant women was voluntary, and informed consent was obtained prior to data collection. Confidentiality, anonymity, and the responsible use of data collected through surveys, interviews, and narratives were ensured. The research protocol was reviewed and approved by the GITA Research Group of the Autonomous University Corporation of Cauca, ensuring compliance with ethical guidelines for research in health and social sciences. Furthermore, the study was carried out in accordance with Decree 1072 of 2015 and the Colombian Technical Guide GTC 45 for hazard identification and risk assessment, ensuring methodological rigor and ethical responsibility in the evaluation of occupational risks. Special attention was given to the condition of the study population, avoiding any form of harm and promoting the use of the findings to improve health and working conditions in rural contexts..
Publisher: Innovative Research Publishing

1. Introduction

Currently, agriculture has experienced a considerable impact from advances in agrochemicals, which are chemical substances frequently used in agricultural production to control pests, diseases, and weeds [1] as well as improve production. For example, in potato cultivation, agrochemicals play a fundamental role in protecting and increasing the yield of this important global crop [1]. They are generally divided into three main groups: herbicides, insecticides, and fungicides.

In Colombia, potato production plays a vital role in both the rural and national economies, contributing approximately 3.3% to the Gross Domestic Product (GDP) [2]. Around 125,000 families in Colombia derive their income from potato production, which is estimated to generate over 20 million workdays annually, according to FEDEPAPA [3]. Colombia boasts a wide range of potato varieties, all registered with the ICA (Colombian Agricultural Institute), and 90% of production is concentrated on the Diacol , Capiro, Parda Pastusa, and Pastusa Suprema varieties, due to their genetic improvements [3]. The need to improve productivity led to the implementation of inputs, which in turn generated negative impacts due to the misuse and application of agrochemicals. This has had detrimental consequences for water, soil, and air quality, severely affecting farmers [4].

The excessive use of agrochemicals in agriculture has negative effects on human health. Over time, it has been observed that these products have caused impacts on the environment and human health [5]. This is especially notable among women farmers, who play a crucial role in agriculture, food production, and distribution, representing 43% of the agricultural workforce worldwide [6]. Similarly, this is observed among those who work in activities involving the handling and direct application of these agrochemicals. According to the FAO, in Asian countries, the percentage of women working in agriculture is estimated to be higher than that of men [7].

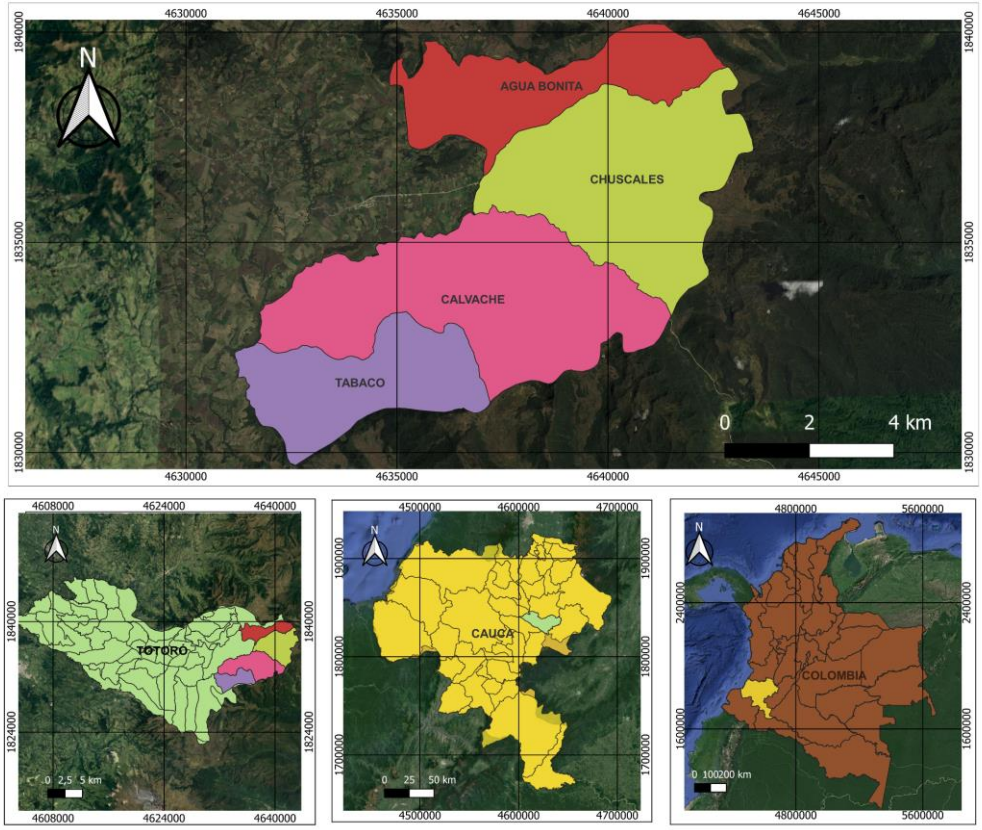
Although there are some diagnoses on the subject, they generally do not have a specific focus aimed at women, therefore it is necessary to have a local diagnosis. Given that the organizations dedicated to environmental issues consider it critical [8].

Given the significant influence of rural women on agricultural production, an occupational health assessment was conducted in the Gabriel López district (Totoró, Cauca) on women farmers exposed to agrochemicals in potato crops in the rural communities of Chuscales, Calvache, Tabaco, and Agua Bonita. The aim was to characterize the work environment and evaluate the hazards associated with agricultural work for women exposed to agrochemicals. By addressing this issue at the local level, more effective interventions and policies can be designed to address the specific concerns of women farmers, while simultaneously promoting safer and more sustainable management of agrochemicals in the region's agriculture.

2. Methodology

2.1. Study Area

In southwestern Colombia lies the township of Gabriel López, belonging to the municipality of Totoró, located in the eastern region of the department of Cauca. It sits in the central Andes mountain range, with altitudes ranging from 2,800 to 3,600 meters above sea level [9]. This territory is ideal for potato cultivation. Planting of this tuber should take place between 2,400 and 3,800 meters above sea level, while the appropriate temperature ranges from 8 °C to 18 °C. Temperate and cold zones with rainfall of 600 to 1,200 millimeters are the most recommended [10]. This study focused on the rural reserve communities of Chuscales, Calvache, Agua Bonita, and Tabaco, as shown in Figure 1.



Original Work

Figure 1.
Gabriel López district (Totoró - Cauca).

2.2. Study population

In the study area, a total of 70 plots were identified, corresponding to potato cultivation, applying the finite population formula Equation 1 [11] the minimum number of plots to visit is 27, in order to facilitate a statistically significant average, 40 was established as the final sample size.

(Equation 1)

$$h = N/[p^2(N-1)+1]$$
$$h = 70/[0.05^2(70-1)+1] = 27$$

Where:

h: Sample size

N: Total population

p: 0.05, probability of error

To identify and assess occupational risks, information was collected from 80 women, distributed equally among the four rural communities: Chuscales, Calvache, Agua Bonita, and Tabaco. Inclusion criteria were: residing in one of the four rural communities of the Gabriel López district, being a female farmer, working in potato farming, having been exposed to agrochemicals for more than 5 years, and giving voluntary consent to participate in the study.

2.3. Methodological Instruments

Were used, an effective tool for collecting information from the study population. Surveys allowed researchers to gather sociodemographic data, lifestyle information, symptoms, health history, and risk perceptions related to hazardous waste disposal, as was the case in the study by García [12]. Interviews and narratives were also employed, enabling researchers to understand the experiences and situations that can only be obtained through the population's own accounts, as was the case in the Narrative Inquiry study [13]. The use of checklists, useful for evaluating variables such as risk perception among rural women, provides a richer and more nuanced understanding of their experiences [14].

Ten plots were visited in each village, and the Colombian technical guide GTC 45 [15] was applied to determine the level of risk from low to critical that could affect the women working in the area. This assessment was carried out in each identified activity of the potato production process. For both the identification and assessment of occupational health risks for exposed women, two phases were considered:

Phase I. Characterization of the occupational environment of women exposed to agrochemicals in the study area; this phase included two activities:

a. Occupational hazards were identified , the work environment and performance in activities related to potato cultivation and production were evaluated using the Colombian technical guide GTC 45 [15].

b. Analysis of potato cultivation processes and activities , variables such as hours of exposure to pesticides, repetitive manual labor, adverse working conditions are analyzed, in accordance with Decree 1072 of 2015 [16] also known as the Single Regulatory Decree of the Labor Sector.

Phase II. Assessment of the occupational risk of women exposed to agrochemicals in the study area.

Were evaluated in terms of their probability of occurrence and their impact on the safety and health of female workers. A risk level, ranging from low to critical, was assigned to each of the identified hazards. Using a list of tasks, processes, and activities derived from the hazard identification, the type of risks (physical, chemical, biological, psychosocial, biomechanical, and natural) could be assessed in order to subsequently establish action plans. For the evaluation of each risk identified for the study area, the different classification levels within GTC 45 [15] indicated below, were taken into account:

- Deficiency Level (ND) refers to the magnitude of control measures that may exist to address risks and determines how adequate the control is. The deficiency level assessment is classified into four categories: Very High (VH): Value of 10, High (H): Value of 6, Medium (M): Value of 2, and Low (L): No value assigned.
- Exposure Level (NE) : GTC 45 [15] defines the Exposure Level (EL) as the situation of exposure to a hazard that occurs during a specific time in the workday. The exposure level assessment is classified into four categories: Continuous (EC) : Value of 4, Frequent (EF) : Value of 3, Occasional (EO) : Value of 2, and Sporadic (EE) : Value of 1.
- Weighting level (NP) , defined by the correlation between ND and NE, reflecting the relative importance of each variable evaluated. NP = ND x NE.
- Consequence Level (NC) refers to the measure of the severity of the consequences that may result from an identified risk in the workplace. The consequence level assessment is classified into four categories: Fatal or Catastrophic (F) : Value of 100, Very Serious (VS) : Value of 60, Serious (S) : Value of 25, and Minor (M) : Value of 10.
- Risk level (NR) . This is defined as the magnitude of a risk resulting from the product of the consequence level (NC) and the probability level (NP), which allows for the identification of priorities, the development of strategies, and compliance with regulations, corresponding to NR = NP x NC.

The risk level is classified into 4 categories: Level I : Value of 4,000-600, qualifies as unacceptable, Level II : Value of 500-150, qualifies as unacceptable or acceptable with specific control, Level III : Value of 120-40 qualifies as acceptable, and finally there is Level IV : Value of 20 which also qualifies as acceptable.

3. Results and Discussion

Table 1 presents the sociodemographic characteristics resulting from the analysis of surveys and interviews with 80 female farmers who perform various activities related to potato production, such as land preparation, fertilization, crop fumigation, and harvesting, in the rural communities of Chuscales, Calvache, Tabaco, and Agua Bonita. Their ages range from 31 to 45 years. Regarding education, most have only completed primary school, a large percentage have been involved in agriculture for between 1 and 5 years, and only 8% have more than 31 years of experience. The 46-year-old group, representing one-third of the sample, may be at risk of acute poisoning due to prolonged exposure to organophosphates for more than 5 years, as indicated in the article "Organophosphate Poisoning" [17]. This exposure affects glomerular filtration rate (GFR) tests, which assess kidney function in the exposed community.

Table 1.
Socio-demographic data.

Age	**N(80)**	**%**
15 to 30	24	30
31 to 45	33	41
46 and up	23	29
Level of education	N(80)	%
Primary	40	50
Incomplete high school	23	29
High school diploma	14	17
Technical	3	4
Years of exposure	N(80)	%
1 to 10	36	45
11 to 21	12	15
22 to 31	19	24
More than 32	13	16

3.1. Characterization and Assessment of Occupational Hazards for Women Potato Farmers

Variables that influence the health and well-being of working women were taken into account, such as hours of exposure to pesticides or repetitive manual labor, among others, which can have harmful long-term health effects. These variables are included to assess chemical, physical, biological , psychosocial, biomechanical, and natural risks. This analysis is conducted in accordance with Decree 1072 of 2015 [16] also known as the Single Regulatory Decree for the Labor Sector.

Figure 2 shows the results of the chemical risk characterization and assessment , distributed across four risk levels, from lowest to highest (I to IV). At level I, the Tabaco village has the highest incidence, with 20%. At level II, the Agua Bonita and Calvache villages are predominant, both with 24%. Level III represents a significant risk, as all four villages evaluated show high percentages, with Chuscales standing out at 41%. At level IV, the highest risk level, Tabaco again stands out with 36%, suggesting an acceptable risk, although with the need to implement additional improvements if available.

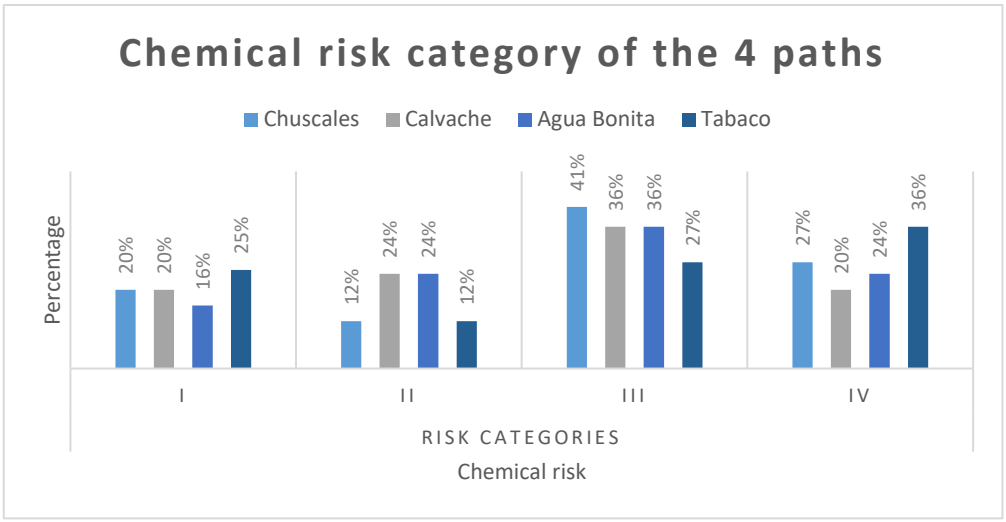


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Figure 2.
Chemical risk category of the 4 villages.

Critical activities were identified at levels I and II, especially in Chuscales. These levels indicate risk and can even be fatal if ingested. Exposure can occur through fumigation with agrochemicals such as parathion, categorized as level I in toxicological terms, or through the consumption of food grown in the area. Women working near potato crops are constantly exposed to agrochemicals because they fumigate without adequate protective equipment. This lack of protection increases the risk of short-, medium-, and long-term illnesses, including Hodgkin's lymphoma, according to studies such as [17].

At a biological and hormonal level, women are more vulnerable to the effects of agrochemicals, making them prone to illnesses such as cancer, miscarriages, birth defects, and fertility problems. Furthermore, agrochemicals accumulate in the bodies of breastfeeding mothers and contaminate breast milk, as noted in the article "Chemical Contaminants and Breastfeeding" [18]. For example, glyphosate, a common herbicide, has been classified as genotoxic, causing damage to organs such as the liver and kidneys in exposed individuals [19] as well as damage to the nervous system, mostly due to agrochemical exposure [20].

Figure 3 reveals the physical risk associated with daily exposure to non-ionizing radiation (sunlight). The following most representative percentages were identified by level: Level I: Calvache (17%); Level II: Calvache (17%); Level III: Chuscales (67%), Agua Bonita (67%), Calvache (58%), and Tabaco (54%); and Level IV: Tabaco (23%). This distribution shows a higher concentration of risks in Levels III and IV, particularly in Chuscales and Agua Bonita, which underscores the need to implement specific protection measures against prolonged sun exposure.

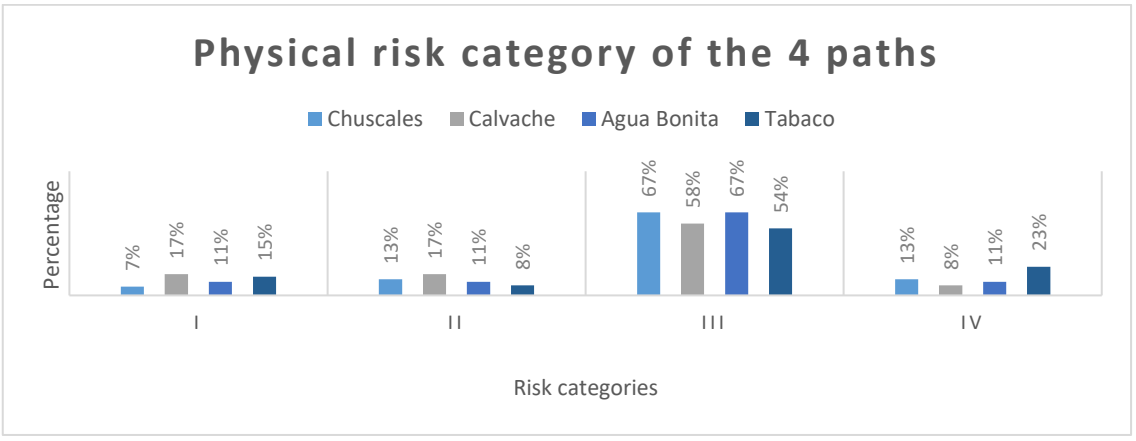

Figure 3.
Physical risk category of the 4 villages.

In the four rural communities, a higher level III physical risk was identified due to climatic conditions such as humidity, solar radiation, and cold in the páramo, which can cause illnesses such as kidney disease, high blood pressure, and respiratory problems [21]. According to the Fatal Occupational Injuries census, 2,233 agricultural workers have died while performing agricultural activities, with tractor rollovers being a recurring cause [22].

Biological risk is of great relevance in agricultural activities, according to Figure 4 the risk has been classified into several levels, level III is the most representative with the highest representation Calvache with 57%, followed by Agua bonita (50%), Chuscales (43%) and finally Tabaco (17%).

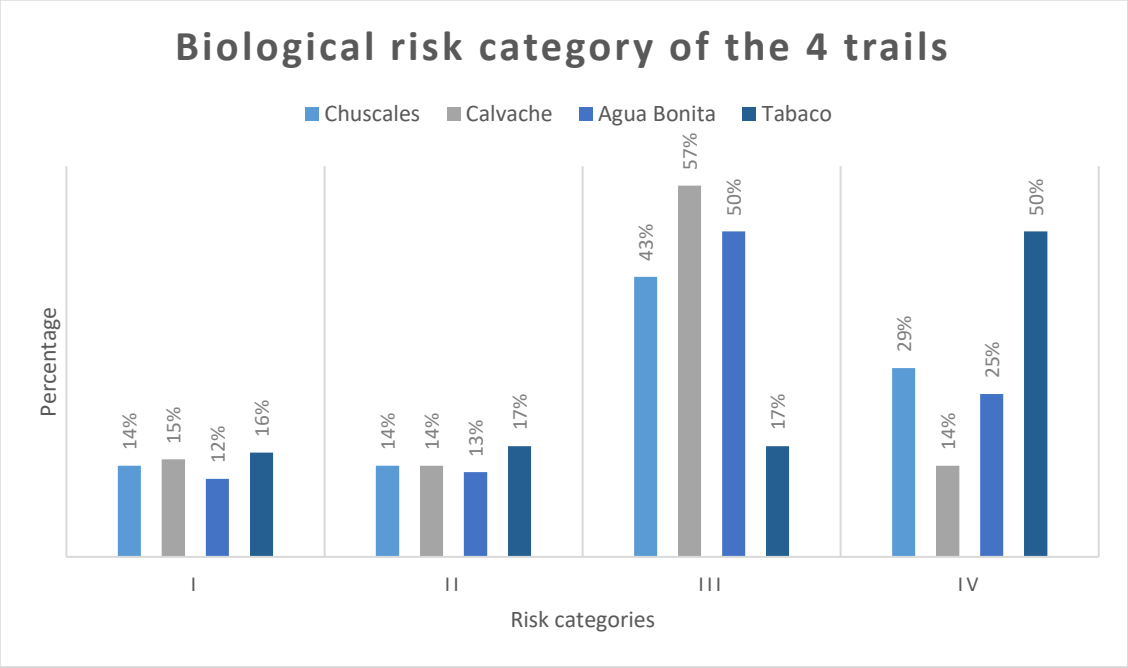

Figure 4.
Biological risk category of the 4 villages.

There is direct and indirect exposure to biological hazards, especially through contact with animals and organic fertilizers, which can cause infections, allergies, and toxicity in agricultural workers. Biological hazards can arise from factors such as exposure to agrochemicals, vector-borne diseases, or pathogens present in the soil. All infections involve an agent (or pathogen), a host, and the environment. Some pathogens require intermediate hosts to complete their life cycle or are transmitted by vectors [23]. It is essential to recognize these threats and establish preventive measures to protect the agricultural community, considering routes of exposure such as skin, inhalation, and the digestive system [24].

Through the characterization and assessment of biomechanical risks (Figure 5), four levels of exposure were identified: Level I: Calvache registered the highest percentage (7%), Level II: Calvache presented 21%, Level III: Chuscales reached 63% and Tabaco 62%, finally in relation to Level IV: Agua Bonita obtained 31%.

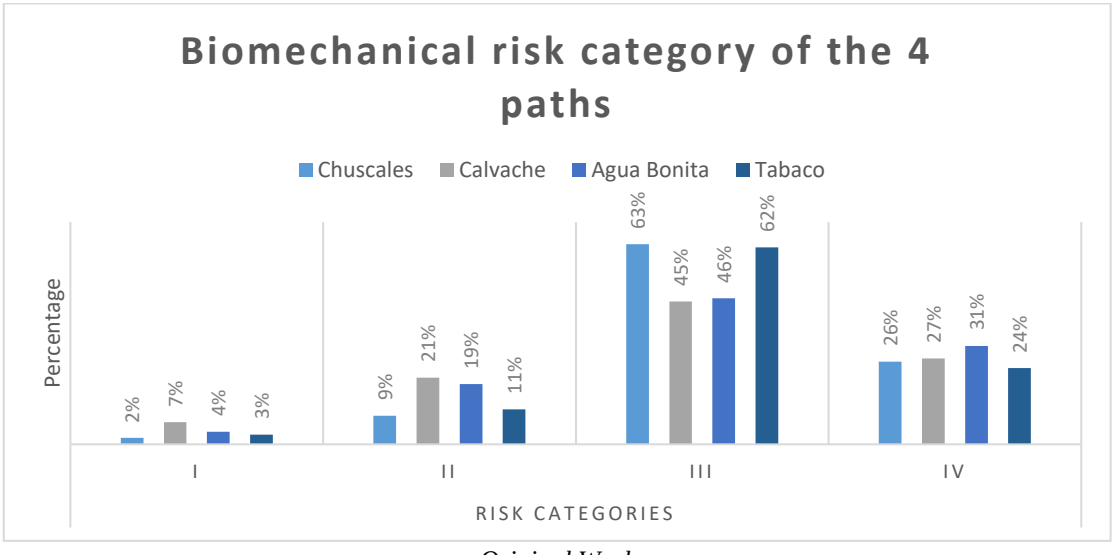

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Figure 5.
Biochemical risk category of the 4 villages.

In the four rural communities analyzed, biomechanical risks associated with agricultural activities such as land preparation, planting, harvesting, and transporting potato sacks were identified. These risks are linked to repetitive movements, postural overload, and awkward positions. These conditions generate musculoskeletal injuries that limit limb mobility and reduce work performance. In Latin America, particularly in Colombia and Chile, 66% of workers report lower back problems due to prolonged workloads and the type of activities performed [25]. For rural women in the area, these injuries represent a critical health risk, underscoring the urgency of implementing preventive strategies such as: ergonomic tools to minimize physical exertion, training in proper posture and stretching/strengthening exercises, and adaptive technologies that reduce manual labor during work [26, 27]. These measures, along with a proactive prevention culture, are key to ensuring safe working environments in Gabriel López and other areas with similar agricultural practices [28].

Psychosocial risks in the workplace can encompass various aspects, such as workload, control over tasks, social support, work-life balance, workplace violence, harassment, and discrimination, among others. Assessing these risks is crucial for designing strategies to prevent and promote mental health in the workplace. Figure 6 presents the results regarding psychosocial risks experienced by female farmers due to forced work schedules under challenging conditions. A higher incidence of Risk Level III was found in the villages of Tabaco (67%), Calvache (58%), Chuscales (56%), and Agua Bonita (55%), indicating a high level of stress and psychological difficulties.

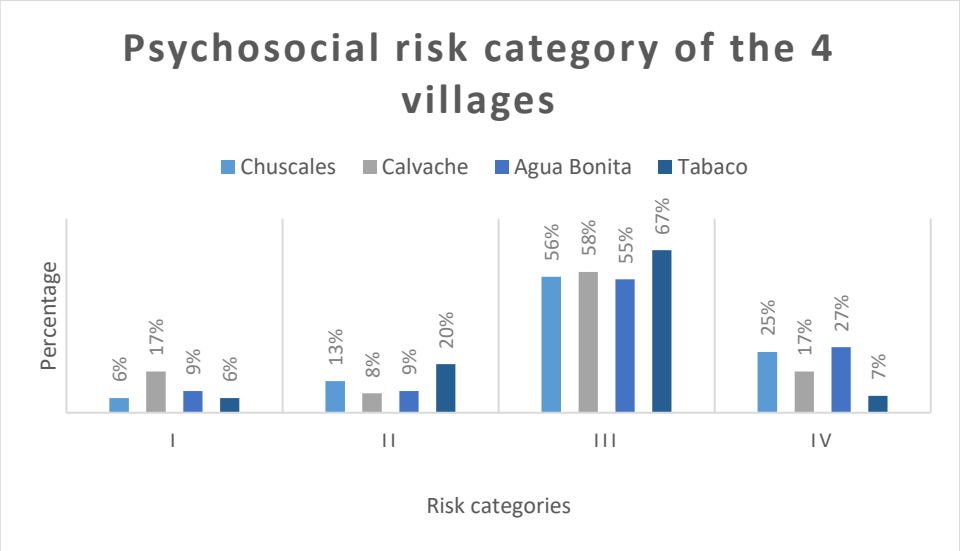

Figure 6.
Psychosocial risk category of the 4 villages.

In the four rural communities of the Gabriel López district, a higher percentage of level III psychosocial risk was identified, highlighting the urgent need to improve working conditions. These include grueling workdays and prolonged exposure to adverse weather conditions, such as intense solar radiation and rain, which contribute to physical and mental exhaustion. Previous studies in the banana industry confirm that these conditions generate chronic stress, irritability, and a decline in the overall well-being of workers, affecting their physical and emotional health [29].

Regarding the study area, it is a priority to implement measures that foster mutual respect among workers in order to guarantee a healthy work environment. Given the presence of identified psychosocial risks, a comprehensive intervention is required, including: equity and inclusion policies to ensure equal treatment among teams, with an emphasis on protecting female farmers [30]. Review of work schedules to align them with safety standards, along with the provision of protective equipment against adverse weather conditions (intense solar radiation, extreme rainfall) [31]. Preventive monitoring systems that include agile mechanisms for conflict resolution and early identification of occupational risks, and specialized psychosocial programs for managing occupational stress, focusing on resilience tools and emotional support. These strategies aim to strengthen inter-team collaboration and prioritize the overall health of female workers, aligning with ILO guidelines for safe agricultural environments. The coordination of these actions will mitigate the identified risk factors and promote a sustainable labor model.

Figure 7 illustrates the natural hazards to which the four rural communities are exposed. This graphic representation classifies the areas according to the level of risk associated with various natural phenomena, thus facilitating informed decision-making in urban planning, land management, and risk management. Regarding the natural risk related to landslides caused by rainfall, the following is observed: at level I, the Tabaco community has the highest percentage with 16%; at level II, Agua Bonita leads with 20%; for level III, Calvache registers 64%, closely followed by Agua Bonita with 60%; finally, at level IV, Chuscales leads with 25%.

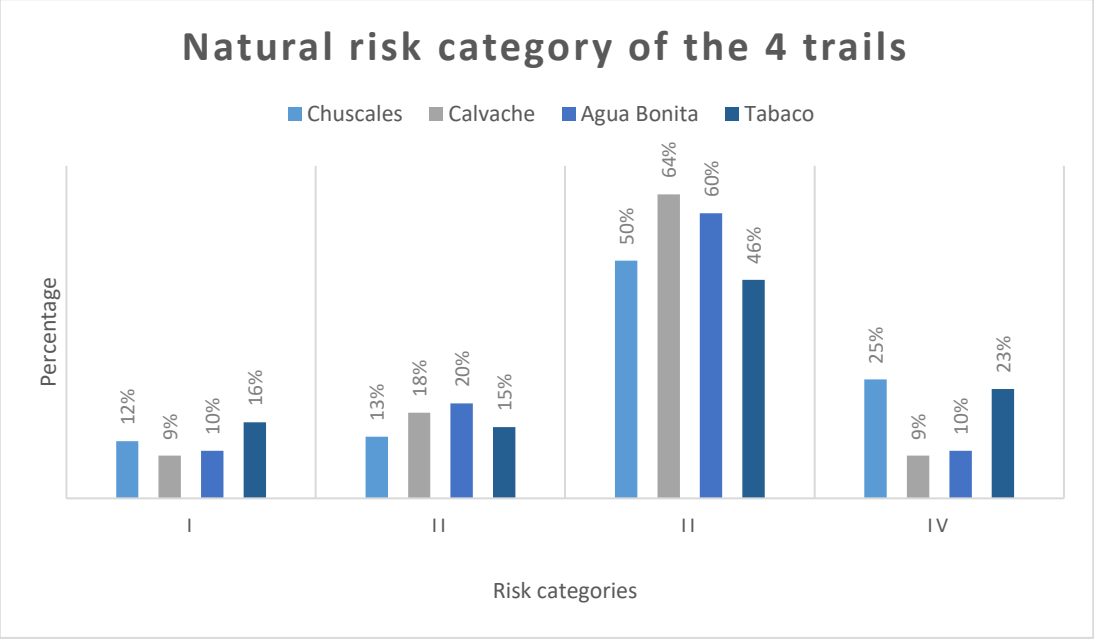

Figure 7.
Natural risk categories of the 4 villages.

The four hamlets of the Gabriel López district are located in a paramo zone, characterized by its vegetation and climatic conditions that favor frequent rainfall. To date, no landslides or mudslides have been recorded, suggesting possible geological stability in the region. However, potato cultivation, which has been the main source of sustenance for these hamlets for generations, has exerted constant pressure on the soil due to prolonged agricultural practices and the terrain's characteristics. This pressure increases the risk of landslides and degrades soil fertility [32].

Natural hazards in the area are closely linked to intensive land use and overexploitation, where the four villages have maintained the same potato cultivation techniques for years [33]. This is compounded by the high adaptability of pests, which has led to an increase in the use of chemical agricultural inputs. To mitigate these hazards, studies and practices related to green agriculture are currently being promoted. The combination of forage plants, shrubs, and even trees contributes significantly to the conservation of water recharge areas, improving hydrological regulation and stabilizing and enriching the soil [34].

Public risk encompasses the categories related to security and risk in the Gabriel López area. As shown in Figure 8 a level III public hazard risk was identified, representing percentages of 57% for Calvache, 46% for Tabaco, 45% for Agua Bonita, and 34% for Chuscales. The Gabriel López district's economy is primarily based on agricultural production, a sector vulnerable to risks such as armed conflict.

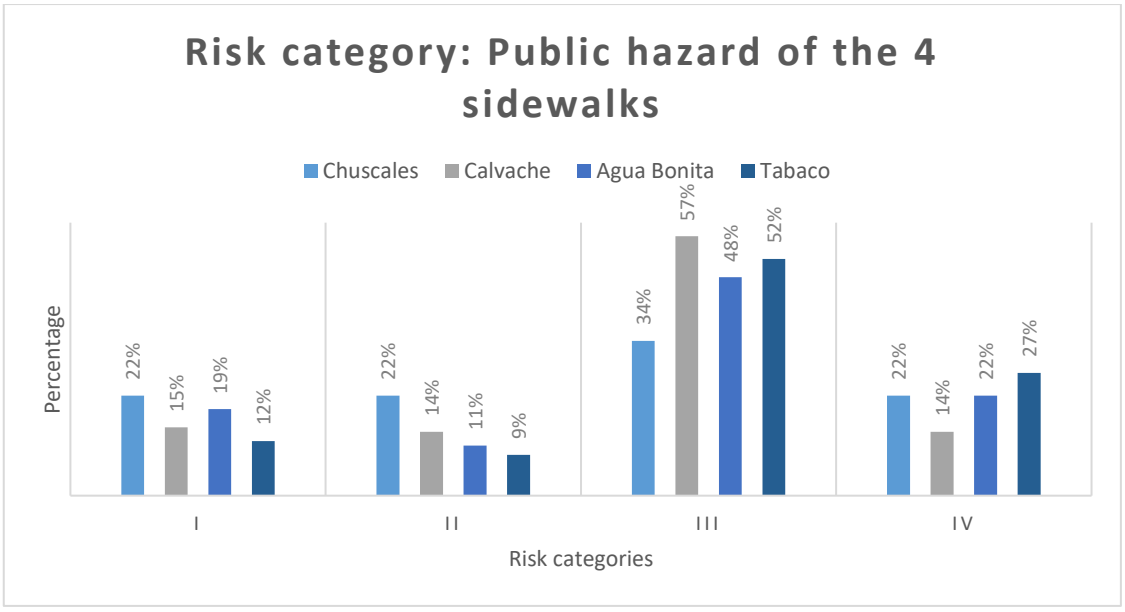

Figure 8.
Public irrigation category of the 4 villages.

In Level III armed conflict zones, it is advisable to implement peace programs to overcome the fear and uncertainty that hinder agricultural activity, vital for subsistence. Rebuilding the social fabric through agreements and programs is crucial, such as the Development Programs with a Territorial Approach (PDETs), which are a key tool in the post-conflict framework in Colombia. These programs seek to implement Comprehensive Rural Reform (CRR) in the rural areas most affected by the armed conflict [35]. The PDETs aim to transform these territories through the direct participation of the local population, promoting reconciliation and progress. These projects have had a positive social impact. The implementation of dialogues and peaceful resolution mechanisms could mitigate these public problems, generating stability and improving economic conditions. This approach is supported by the positive impact that the peace agreement had on the agricultural development of the department of Huila, whose economy, like that of Gabriel López, depends mainly on this sector.

3.2. Assessment of Occupational Health Risks in Female Farmers

The results of the assessment with different classification levels within GTC 45 (Exposure level, Probability level, Consequence level, Risk level) are presented below, based on activities such as storage, land preparation, control of agrochemicals and harvesting [15].

As shown in Figure 9 the Exposure Level (NE) was 2 for all activities in Agua Bonita and Calvache, indicating occasional exposure. In Chuscales, this same level was recorded for agrochemical control and harvesting activities. In Tabaco, an NE of 2 was observed for land preparation, agrochemical control, and harvesting.

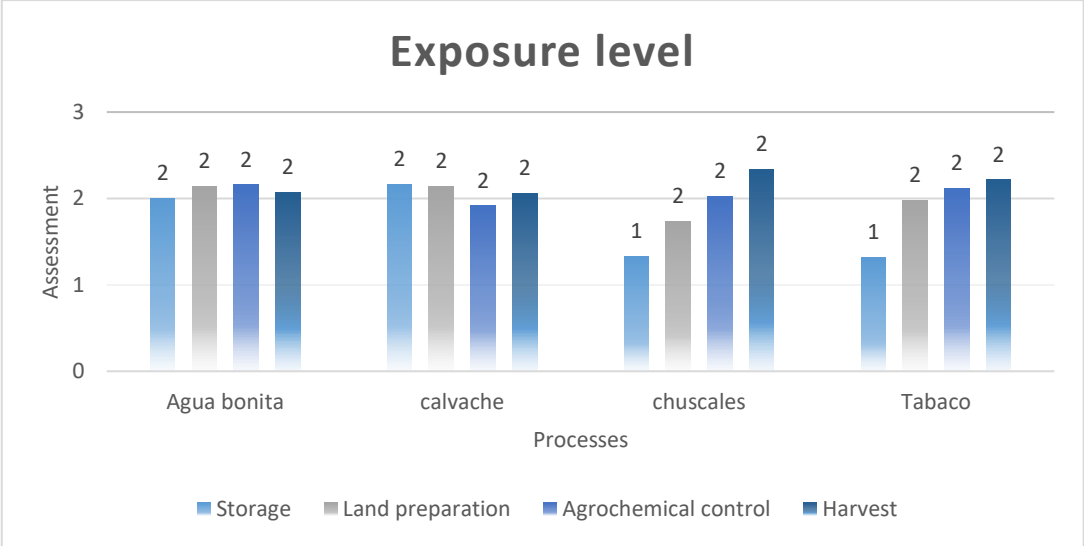

Figure 9.
Exposure level category of the 4 villages.

In general, NE exposure was occasional in all four villages, which, according to GTC 45, corresponds to a "situation of exposure at some point or for a short period of time." Although this level is considered low, poor agricultural practices are evident [36] that increase health risks, especially for rural women. Therefore, it is necessary to establish control measures such as the substitution of chemical products, the strengthening of administrative controls, or at least the proper use of personal protective equipment [37].

Probability Level (NP). In Figure 10 it is clearly evident that the highest NP is present in activities related to control with agrochemicals, where there is a similar rating for the 4 villages, the lowest was for Chuscales (7), followed by Agua Bonita and Calvache (8) and the highest was for Tabaco (9), indicating that there is a representative average NP for the 4 villages.

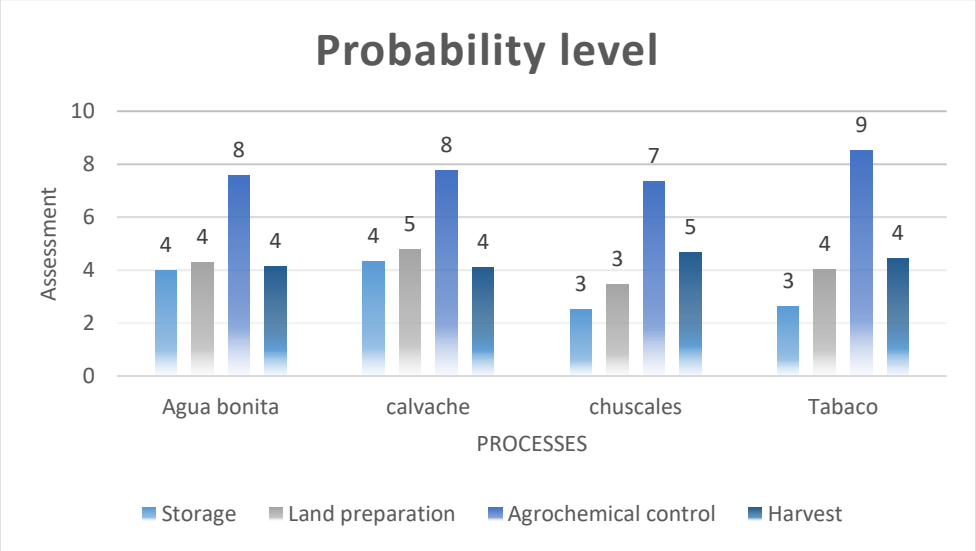

Figure 10.
Probability level category of the 4 villages.

The results indicate a medium NP (M) for control with agrochemicals, the highest among the processes evaluated for the 4 villages. Despite having a medium NP, GTC45 [15] establishes that there is continuous or frequent exposure to these chemicals, which is susceptible to some type of damage. It is necessary to take measures, since this finding is consistent with previous studies that indicate that the excessive use of agrochemicals can generate significant negative impacts on both public health and water systems [38].

Level of consequence(NC): As observed in Figure 11 , the most representative activity for the consequence level was found to be the control with agrochemicals, thus obtaining a mild result (24) in Agua Bonita, a serious result (31) in Calvache, a very serious result (37) in Chuscales, and tobacco also has a very serious level (35) where serious irreparable injuries or diseases may occur.

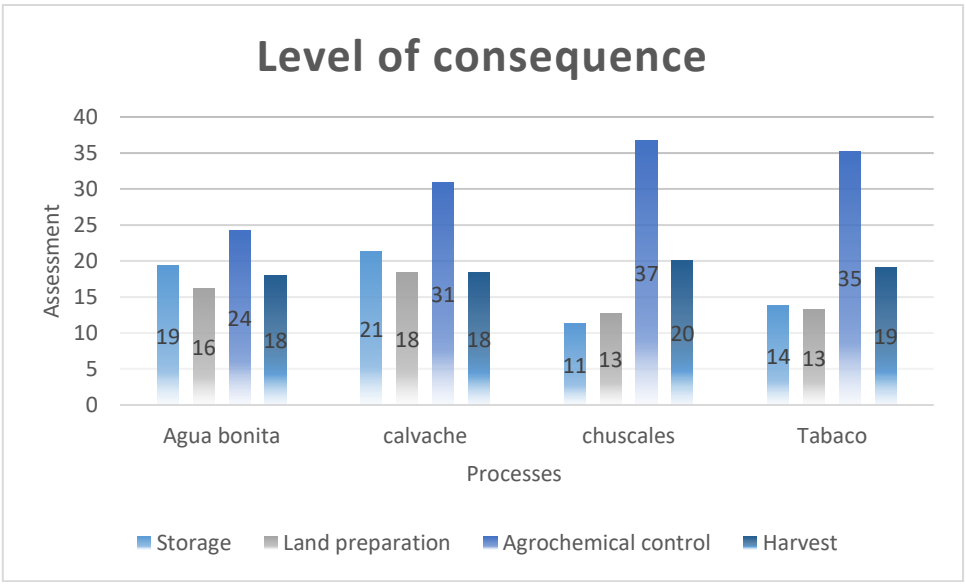

Figure 11.
Category level of consequence of the 4 villages.

A serious NC (G) is evident in the control of the agrochemical, remaining in the highest range compared to the other processes studied in the four villages of the Gabriel López area. GTC 45 [15] indicates that the assessed impact or risk can generate significant effects on health, the environment, and the processes involved. In human health, it can cause serious injuries and even death, and in the environment, considerable contamination of water resources, air, soil, and species. For this reason, it is urgent to implement immediate prevention and mitigation measures to avoid more serious long- term damage [39] .

Level of risk (NR): Figure 12 indicates that the activity with the most relevance for the risk level in the four villages is the control with agrochemicals, with Chuscales and Tabaco being the most affected villages with a rating of 300 and 270 respectively (level ll), followed by Calvache with a rating of 240 (level ll), which are not acceptable and a specific control must be carried out.

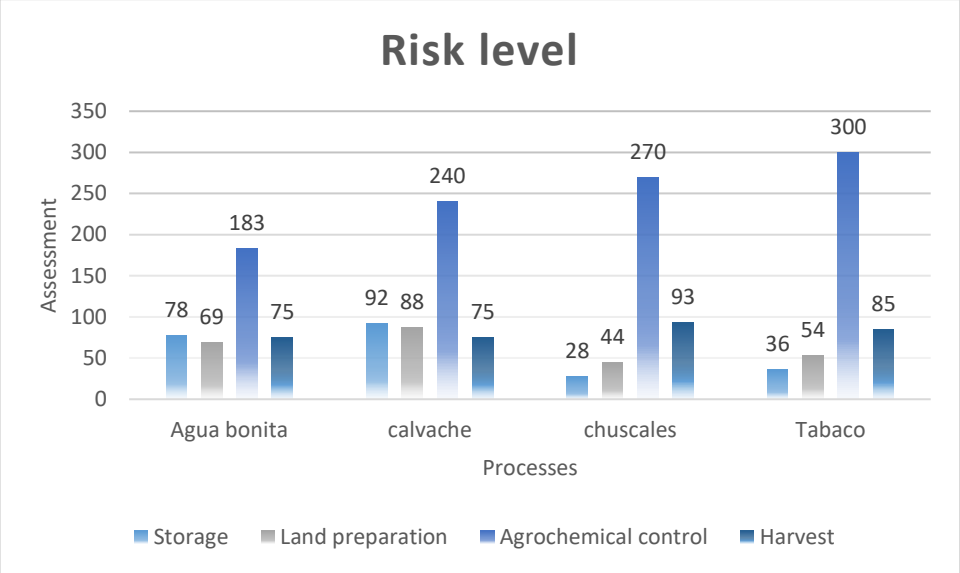

Figure 12.
Risk level category of the 4 villages

A Level II level was obtained in all four villages for agrochemical control, indicating that Tabaco and Chuscales are the most affected villages due to prolonged contact with chemical substances. With a Level II NR (Normal Risk Assessment), corrective measures must be implemented according to GTC 45 [15] to prevent injuries and to implement preventative measures to avoid environmental impact. Level II contamination is controllable with appropriate mitigation measures, thus protecting the health of rural women exposed to these agrochemicals, the environment, and the health of the general population [40].

4. Conclusions

The study determined critical occupational risk levels (Level I according to GTC 45) in women exposed to agrochemicals, with Risk Level (RL) values exceeding 600 points in key activities such as soil preparation, fumigation, and harvesting in the Calvache village. This risk was directly associated with continuous exposure to organophosphates without adequate protective equipment, where 34% of the female farmers showed symptoms consistent with kidney damage and 21% reported chronic dermatological disorders. Bioaccumulation of toxins in lactating women showed plasma concentrations 3.2 times higher than in the control group, according to the biomarkers analyzed .

It is recommended to train workers in the proper use of personal protective equipment, implement occupational health surveillance measures, and establish strategies to reduce working hours in order to promote a healthier work environment. It is urgent to promote sustainable agricultural practices, optimize the use of agrochemicals, and establish strict regulations for their storage and disposal in order to protect human health and ensure the conservation of ecosystems.

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