

A Study on Occupational Health in the Marble Industry in Mexico: The Case of Tepexi de Rodríguez-Puebla

Teodoro Alarcón-Ruiz^{1,2}, Luis Enrique García-Santamaría², Yésica Mayett-Moreno³, Eduardo Fernández-Echeverría⁴ & Gregorio Fernández-Lambert^{2*}

¹División de Estudios de Posgrado e Investigación, Tecnológico Nacional de México/IT de Puebla, Avenida Tecnológico 420, Col. Maravillas, 72220, Puebla, México

²Laboratorio de Logística y Sustentabilidad en Economías Emergentes, Tecnológico Nacional de México/ITS de Misantla, Km. 1.8 Carretera a Loma del Cojolite, 93850, Misantla, Veracruz, México

³Universidad Popular Autónoma del Estado de Puebla. 17 Sur 901, Barrio de Santiago, 72410, Puebla, México

⁴Departamento de Ingeniería Industrial, Tecnológico Nacional de México/ITS de Zacapoaxtla. Carretera Acuaco-Zacapoaxtla Km. 8, Col. Totoltepec, 73680, Zacapoaxtla, México

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The existing literature lacks a unified perspective on the impact of occupational health in the marble industry, especially in developing countries. This study aims to enhance current knowledge by exploring how operational conditions and work activities affect workers' health. In the municipality of Tepexi de Rodríguez, Puebla, Mexico, two marble companies and 27 workers participated. In 2021, lighting, noise, and operational conditions were measured, and in 2024, sleep disorders and occupational fatigue were evaluated. The three-year gap between study periods resulted from accessibility and logistical issues. The study used the LEST method, NOM-011-STPS-2001 and NOM-025-STPS-2008 standards, and the Pittsburgh and Yoshitake instruments; data were processed using Ergoniza® software. Results show a physical workload of 7.7, mental workload of 3.0, psychosocial aspects of 4.3, and work time of 6.9 (on a scale of 0 to 10). Noise levels reached 92.26 dB, natural lighting was 899.6 lx, and artificial lighting was 269.4 lx. The sleep disorder index was 7.0, and occupational fatigue showed 2.3 out of 5 for physical fatigue, 1.9 for mental fatigue, and 2.1 for mixed fatigue. These findings reveal a severe physical workload in the cutting, polishing, and packaging areas, correlating sleep disorders to work areas. Increasing the sample size and randomly selecting workers for dynamic system modelling is recommended to explain the correlation between working conditions and productivity. This study underscores the need to improve working conditions to mitigate health impacts, offering practical insights for marble companies and health organizations.

Keywords: Collateral damages, Environmental conditions, Ergonomic evaluation, Lighting, Noise

Introduction

In the last 60 years, the demand for marble-derived products in Mexico has grown at an annual rate of 3%, especially in handicrafts and construction-related products.¹ The processes of marble extraction and transformation require a set of economic and technological resources, as well as the skill and expertise of the human resource.² Various academic works at the international and national levels indicate that the processes of marble extraction and transformation negatively impact the health and safety of workers.³⁻⁵ In this field, it has been documented that the marble extraction industry in Turkey faces issues related to occupational safety, health damage to workers, and impacts on ecosystems.⁶ In Palestine, it is

reported that the environmental conditions to which workers in the marble and stone industry are exposed generate respiratory diseases and traumatic accidents⁷ due to the use of obsolete machines and equipment.

In the American continent, Cuba and Peru report health damages associated with environmental impacts on air and soil due to marble exploitation activities.⁸ In this regard López (2021), justifies these health damages by the lack of training programs and occupational health and safety management systems.⁹ In Mexico¹⁰ it has been reported since 2012 that the productive activities of the marble industry in the Comarca Lagunera generate health damages, ecological damage, and changes to the natural environment. However, it was reported that in Hidalgo-Mexico, the activities of the marble mining industry have negative consequences on workers, associated with sleep disorders and occupational fatigue.¹¹ On the other hand,

*Author for Correspondence
E-mail: gfernandezl@itsm.edu.mx

in the Mixteca Poblana region¹² it is highlighted that the lack of a sustainable waste disposal plan for the residues generated in the extraction and transformation of marble—scraps and sludge—has caused health damage to workers and people living nearby these marble industry. In this regard, work has been proposed to find alternatives to solve the problem of environmental impact caused by the waste from this industry, including those generated in cutting, polishing, during the extraction of dimensional stones in quarries, such as scraps, dust, as well as sludge generated by cutting, re-tapping, or polishing operations in the marble factory.^{13–15} However, there is a lack of studies evaluating the labour and environmental factors affecting the workers with and due to the work, they perform in this industry. In this productive context¹⁶, it is recommended that within the common practices in the marble industry, the continuous evaluation of each process from design to the delivery of the final product should be included as a habitual practice to permanently measure occupational risks for the workers. For this purpose, the ergonomic principles of the LEST method (*Laboratoire d'Economie et Sociologie du Travail*) are an effective method for evaluating the working conditions of any organization.¹⁷ The LEST method, through its five dimensions: physical environment, physical workload, mental workload, psychosocial aspects, and work time, enriched with evaluations for sleep disorders and fatigue, together, allow the assessment of the interaction processes between people and the physical spaces where labour activities take place (Fig. 1).

Although the LEST method contains the dimension of the physical environment (lighting, noise, temperature, vibration), it is recommended that the physical environment be evaluated through the

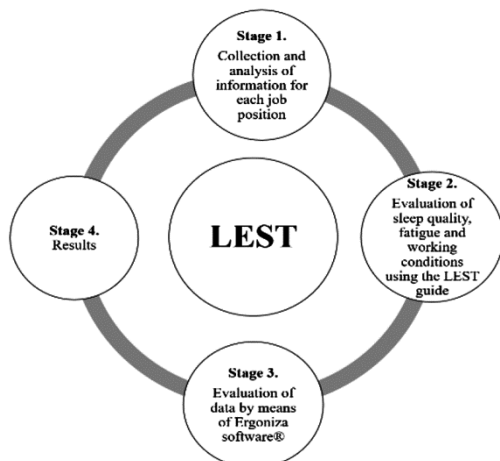


Fig. 1 — Methodological process used in the research

standards of each country.^{6,18} In this regard, LEST proposes that workstations or areas be observed through 16 variables grouped into five dimensions¹⁹; however, the version of the Ergoniza® software for the five dimensions considers fourteen variables; while in other reported studies^{6,19} the number of variables has been adapted to the needs of the workstations in each particular case. Particularly, for the evaluation of sleep disorders, the Pittsburgh questionnaire²⁰ is used, which generates a global score and partial scores for seven factors: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Meanwhile, for the evaluation of occupational fatigue, the Yoshitake questionnaire²¹ is applied, which consists of 30 items distributed in three subscales: the first measures fatigue symptoms for jobs with mixed demands (items 1–10), the second measures mental fatigue (items 11–20), and the last measures physical fatigue (items 21–30). This article analyzes the working conditions of the operational staff in two marble companies in Tepexi de Rodríguez, Puebla-Mexico. Five key dimensions that affect these conditions are addressed: physical environment, physical workload, mental workload, psychosocial aspects, and work time. Within these dimensions, twelve specific variables related to stone cutting, re-tapping, polishing, packaging, and strapping operations are identified and analyzed. Additionally, measurements of the sleep quality index and fatigue associated with the worker are incorporated. The results of this study provide knowledge to the scientific community and the marble mining sector so that their managers can make informed decisions to direct it towards a sustainable industry.

Materials and Methods

This exploratory and descriptive research, with a qualitative approach, non-experimental, correlational, and cross-sectional design²², was conducted in the marble-producing region of Tepexi de Rodríguez-Puebla, in the years 2021 and 2024. Factors affecting working conditions that could impact worker performance in the areas of marble cutting, polishing, storage, and shipping were identified and measured. Characterized as a family industry highly subject to the opening and closing of operations and given the low interest in participating in this research, several companies in the sector were invited. Only two companies and 27 of their workers agreed to participate in this research.²³ These companies operate

3 work shifts of 8 hours, with 5 activities linked to the marble production process (Fig. 2).

Supported by the four stages of the LEST guide (Fig. 1), which allows identifying non-ergonomic factors that could pose risks to workers and diagnosing the environmental conditions of the work²⁴, the study was conducted in two phases: the first between the months of August and December 2021, and the second between the months of April and May 2024. In both cases, the same workers participated, and the same instruments were used. The three-year gap between the two study phases was due to inaccessibility to the study subjects and logistical problems with the company owners. Once these situations were resolved, the study was completed.

Stage 1 involves the study of 5 activities, through on-site observation, performed by 27 workers within

the facilities of the two marble companies participating in this research. Meanwhile, in Stage 2, twelve variables are evaluated with the same study subjects in 2021 across the dimensions²⁵ of physical environment, physical workload, mental workload, psychosocial aspects, and work time. In 2024, for the same study subjects and in the same companies, evaluations of the sleep quality index²⁰ and occupational fatigue²¹ are incorporated (Fig. 3).

In Stage 2, the evaluation of the physical environment focuses on the variables of noise and lighting. Noise was evaluated according to the requirements of NOM-011-STPS-2001⁽²⁶⁾, and the lighting variable was evaluated according to the requirements of NOM-025-STPS-2008.⁽²⁷⁾ The materials used for these evaluations are described in Table 1.

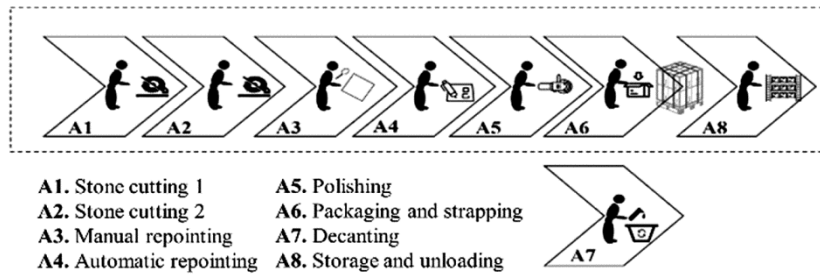


Fig. 2 – Operations associated with the marble industry

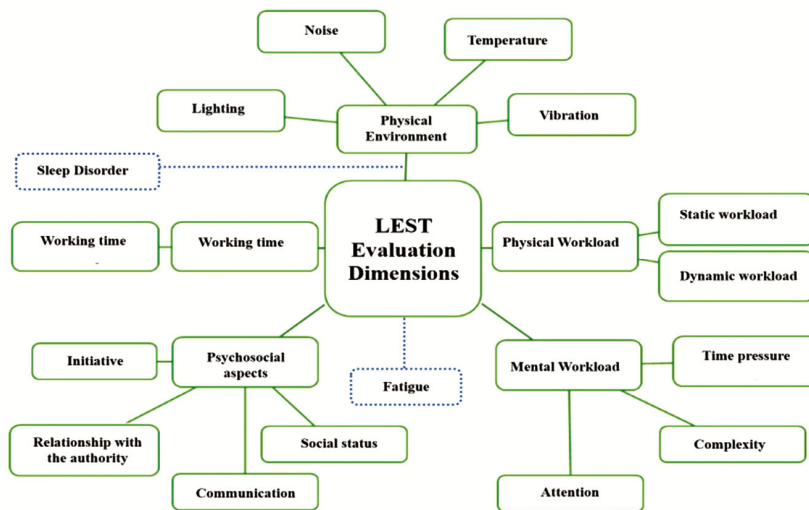


Fig. 3 – Evaluation Dimensions of the LEST Method.

Table 1 — Material to evaluate the dimension of the physical environment

Physical Environment	Standard	Equipment	Study areas
Noise [†]	NOM-011-STPS-2001	Sonometer STEREN HER-403	A1, A2 A3, A4, A5, A6, A7, A8
Lighting ^{††}	NOM-025-STPS-2008	Digital luxmeter brand Steren model HER-410, range of 0-50,000 lux	A1, A2 A3, A4, A5, A6, A7, A8

[†]The conditions for noise measurement were taken from the specifications of the standard

^{††}The measurement points were calculated according to equation 1 of the standard, resulting in 4 measurement points per area

The dimensions of physical workload, mental workload, psychosocial aspects, and work time were evaluated with the 10 variables described in the LEST method.²⁵ In contrast, to measure the sleep quality and fatigue of the workers, the Pittsburgh²¹ and Yoshitake²² questionnaires were used. The Pittsburgh questionnaire helped measure the sleep quality index (PSQI) through open questions related to sleep patterns during the last month. The PSQI index²⁸ is described in Table 2. Meanwhile, the Yoshitake questionnaire²¹ helped to collect data related to the level of fatigue using a Likert scale from 0 to 5 (Table 3). This research uses the²⁹ adapted version in Spanish. This instrument is validated, and its reliability determined with a Cronbach's alpha of 0.89.⁽³⁰⁾

In Stage 3, measurements were taken from the participating study subjects for the dimensions of physical workload, mental workload, psychosocial aspects, and work time, using the LEST method.¹⁹ Information was collected through direct interviews with the workers, who described the activities performed in their job positions. These data were captured according to the LEST method¹⁹ with a specific evaluation for each area as detailed in Table 4. The measurement considered 5 positions of 27 workers

in the two participating marble companies: 78% men and 22% women. The information obtained is both objective and subjective, using quantitative variables about the workers' perception of mental workload and the psychosocial aspects in which they are immersed. The LEST field sheet available in Ergonautas³¹ was used to obtain information.

In Stage 4, the results of these measurements are compared with the report of the occurrence of illnesses and accidents reported by the Mexican Social Security Institute (IMSS) up to April 2020, for the marble industry in Tepexi de Rodríguez, Puebla-México.³²

Finally, the results are presented quantitatively in histograms based on the report provided by the Ergoniza® software and are available at: <https://www.ergonautas.upv.es/>. Meanwhile, the possible correlation between the perception expressed by the worker through the work dimensions and work areas in the marble industry is determined statistically.

Results and Discussion

Evaluation of the Physical Environment of Noise and Lighting using Mexican Standards

The results of the measurements taken at the two companies are shown in Table 5. The recorded values, ranging from 79.8 dB to 114 dB, indicate the exposure of workers to these noise levels. These measurements correspond mostly to a level of SEVERE hearing damage in the decanting, storage, and unloading areas. However, the level of risk is DEEP and higher in the stone cutting areas 1 and 2. It

Table 2 — Scoring and valuation of the PSQI

Score	Description
0 – 5	Considered a good score, indicates satisfactory sleep quality
6 – 10	Moderate score, may indicate acceptable sleep quality, but with some occasional problems
11 – 15	High score, suggests the presence of a mild to moderate sleep disorder
16 – 21	Very high score, indicates the presence of a severe sleep disorder

Table 3 — Scoring and valuation for evaluating fatigue

Score	Description
0 – 1	Score considered "Mild Fatigue"
2 – 3	Score considered "Moderate"
4 – 5	Score considered "Severe"

Table 4 — Scoring and valuation of the LEST method

Score	Valuation
0–1–2	Satisfactory situation
3–4–5	Weak discomfort. Some improvements could bring more comfort to the work.
6–7	Medium discomfort. There is a risk of fatigue.
8–9	Strong discomfort. Fatigue
10	Harmful situation

Table 5 — Noise measurement results†

Work Areas	Measurement*	Requirement**	Risk Level
Stone cutting 1	114.6 dB	85 dB	Deep
Stone cutting 2	95.4 dB	85 dB	Deep
Automatic retaping	92.8 dB	85 dB	Deep
Manual retaping	90.2 dB	85 dB	Deep
Polisher 1	92.6 dB	85 dB	Deep
Packing and strapping	92.2 dB	85 dB	Deep
Decanting	79.8 dB	85 dB	Severe
Storage and unloading	80.5 dB	85 dB	Severe

*Measurement = Average NER (dBA) per work area **Requirement = Permissible dBA by Standard NOM-011-STPS-2001⁽²⁶⁾

†Based on the standard NOM-011-STPS-2001⁽²⁶⁾, 50 measurements were taken in the areas of Stone cutting 1, Stone cutting 2, Automatic retaping, Manual retaping, Polisher 1, Packing and strapping, Decanting, and Storage and unloading

is important to highlight that hearing loss is considered the number one ailment in the world.⁷

Study of Lighting Levels in Operational Facilities

The average lighting values in these areas, which are critical for obtaining the marble block in the factory, is described in Table 6. Measurements were taken at five different times of the day to ensure a comprehensive evaluation of lighting conditions and adapt to operational needs. The work areas evaluated in the two marble companies perform their activities in semi-open spaces, allowing the use of natural light. In this regard, natural lighting measurements in areas A1, A2, A3, A4, A5, and A6 corresponded to 87 lumens, considered acceptable in NOM-025-STPS-2008. However, from 8:30 PM, the artificial lighting provided for the work areas falls below the minimum established level. Therefore, in the processes associated with areas A1, A2, A3, A4, A5, and A6, from 6:00 PM onwards, it is required to adjust to lighting levels that do not compromise the visual safety of the workers (Fig. 4).

Evaluation of the Pittsburgh Sleep Quality Index (PSQI)

From the 27 surveyed workers, an average age of 38.5 years was obtained with a standard deviation of ±8.8. 78% of the surveyed workers were men, and all showed interest in participating in the study. Regarding sleep quality, the average total score obtained from the PSQI was 8.89 ±3.61. The results by work area concerning the sleep quality of the workers is shown in Table 7. For example, in the areas²⁸ (A1, A2, A3, A5, A8) with 20 evaluated workers, the values show (8 < PSQI ≤ 14), indicating

Table 6 — Lighting Measurement Results†

Area	††TMM (24:00 hrs)	†††LFI (Luxes)	Q1*	Q2**
A1 Stone cutting 1	09:30	638.25	YES	NO
	11:00	1047	YES	
	14:30	1011.75	YES	
	20:30	400.5	YES	
	23:30	370.75	YES	
A2 Stone cutting 2	09:30	682.12	YES	NO
	11:00	1021.25	YES	
	14:30	990.75	YES	
	20:30	250.75	NO	
	23:30	262.43	NO	
A3 Manual retaping	09:30	628.5	YES	NO
	11:00	1037.25	YES	
	14:30	1094	YES	
	20:30	470.75	NO	
	23:30	380.75	NO	
A4 Automatic strapping	09:30	610	YES	NO
	11:00	1038.75	YES	
	14:30	1097.75	YES	
	20:30	200.75	NO	
	23:30	200.51	NO	
A5 Polisher	09:30	570.75	YES	NO
	11:00	871.75	YES	
	14:30	917.5	YES	
	20:30	123.01	NO	
	23:30	122.5	NO	
A6 Packing	09:30	753.25	YES	NO
	11:00	1076.75	YES	
	14:30	1105.25	YES	
	20:30	230.25	NO	
	23:30	220.25	NO	

† Source: Based on NOM-025-STPS-2008, the lighting levels were evaluated in the work areas of Stone Cutting 1, Stone Cutting 2, Automatic Retaping, Manual Retaping, Polisher 1, and Packing | †† TMM (Time of measurement) | ††† LFI (Lighting level) | Q1* = Does it comply with NOM-025-STPS-2008? | Q2** = Is there a risk of reflection in the area?

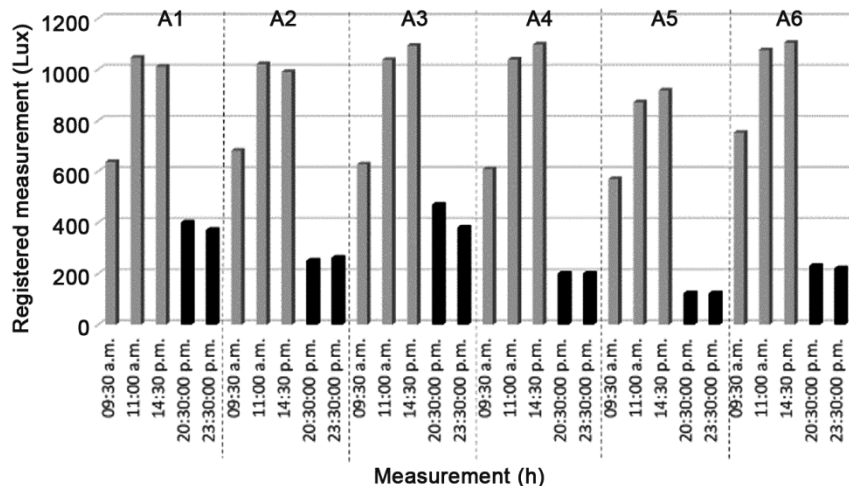


Fig. 4 — Lighting measurement values

Table 7 — PSQI values for areas in the marble industry

Area	Workers	Percentage	Average PSQI	Standard deviation
A1	6	22.22	9.50	4.92
A2	5	18.52	9.00	4.05
A3	3	11.11	10.33	2.05
A4	2	7.41	6.50	1.50
A5	2	7.41	0.00	2.00
A6	2	7.41	7.00	1.00
A7	3	11.11	6.66	2.05
A8	4	14.81	10.00	2.45
Total	27	100.00%		

Table 8 — Aspects of sleep quality according to PSQI

	Measurement	Percentage
Subjective quality (1)	Very good	29.60
	Fairly good	29.60
	Fairly bad	18.50
	Very bad	22.20
Latency (2)	≤ 15 minutes	14.81
	16–30 minutes	55.56
	31–60 minutes	11.11
	> 60 minutes	18.52
Sleep Duration (3)	> 7 hours	0.00
	6–7 hours	33.33
	5–6 hours	44.44
	< 5 hours	22.22
Usual Sleep Efficiency (4)	≥ 85%	44.44
	75–84%	29.63
	65–74%	14.81
	< 65%	11.11
Sleep Disturbances (5)	None in the last month	0.00
	< 1 time a week	77.78
	1–2 times a week	22.22
	≥ 3 or more times a week	0.00
Use of Medication (6)	None in the last month	44.44
	< 1 time a week	29.63
	1–2 times a week	25.93
	≥ 3 or more times a week	0.00
Daytime Dysfunction (7)	None in the last month	14.81
	< 1 time a week	37.04
	1–2 times a week	44.44
	≥ 3 or more times a week	3.70

workers who need medical attention and treatment. In contrast, the areas (A4, A6, and A7) with 7 workers show values of ($5 < \text{PSQI} \leq 7$), indicating they only need medical supervision.

Around 70% of workers perceive their sleep as good; however, they acknowledge facing problems with sleep duration and efficiency, as well as daytime dysfunctions (Table 8). It can be seen in Table 8 that 22.22% sleep less than 5 hours per night, which is associated with health problems.³³ Additionally, 25.93% have low sleep efficiency, suggesting problems maintaining continuous and restorative sleep.³⁴ Although 44.44% of workers do not use any medication to sleep, 55.56% of workers indicate that they do need medication to sleep. Daytime

Table 9 — Scoring and assessment of work fatigue

Items	Measurement of fatigue level	Score obtained	Fatigue level
1–10	Work with mixed demands	2.1	Moderate
11–20	Work with mental demands	1.9	Mild
21–30	Work with physical demands	2.3	Moderate

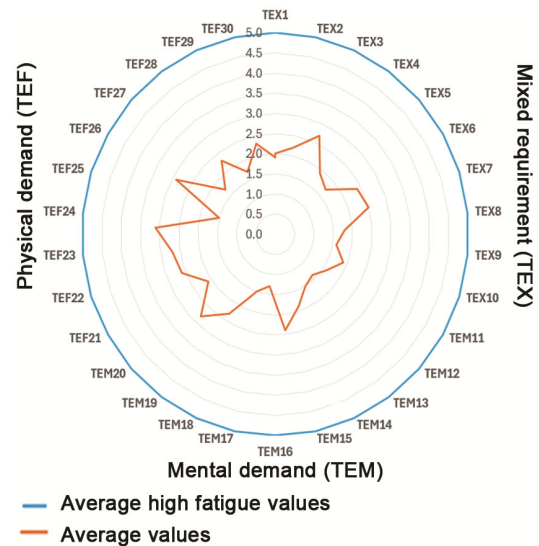


Fig. 5 — Work fatigue level

dysfunction affects 48.14% of participants in this study, which can impact their daily performance.³⁵ These findings highlight the urgent need to improve sleep quality through interventions in sleep latency, duration, and efficiency, and recommend that workers use health services to improve their sleep. These joint actions should be agreed upon between employers and workers.

Evaluation of Work Fatigue

The results of the Yoshitake survey (Table 9) show the assessment of the 27 workers in the eight productive work areas. In this sense, considering the fatigue level evaluation scale established in Table 3, it is observed that jobs with mental demands present a low level of fatigue, while jobs with physical and mixed demands show a moderate level of fatigue.

Additionally, the graphical concentration of the scores obtained from each item of the survey shows that workers present moderate fatigue mainly due to back pain (3.9), followed by thirst during daily work (2.9), and difficulty maintaining the body in the same posture (2.8). The scores obtained for each item of the Yoshitake survey (Fig. 5) indicate a specific need for attention to reduce work fatigue, especially in tasks with high physical and mixed demands, thereby improving the health and well-being of workers.

Evaluation of Working Conditions using the L.E.S.T. Method

The information collected from the work areas was captured in the Ergoniza®¹⁹ software, an online tool that displays the assessment scale based on the score (Table 10) and its graphical representation in the dimensions: physical environment, physical load, mental load, psychosocial aspects, and working times (Fig. 3).

In this sense, the results of direct observation in the workstations allowed gathering information from the described areas (Fig. 2) and related in Table 10, where the highest scores are concentrated in the stone cutting areas 1, followed by packing and strapping, and stone cutting area 2 (Figs 6 & 7).

The estimated values for physical load, mental load, psychosocial aspects, and working times (Fig. 6) are described in Table 11. Note that the harmfulness values

are associated with the dimension of physical load for the stone cutting and packing-strapping areas. The values of strong discomfort (fatigue) are observed in

Table 10 — Evaluated Areas and Results Obtained from LEST Dimensions

Evaluated Area	Observable Position	Result (Average Value)
A1	Operator, Stone cutter 1	6.27
A2	Operator, Stone cutter 2	5.73
A3/A4	Automatic patcher operator	N/A*
	Manual patcher operator	4.91
A5	Polishing machine operator	4.65
A6 / A8	Marble slab packer	5.99
A7	Does not require a specific position	N/A*

N/A* = Human interaction in these areas does not compromise physical load, mental load, psychosocial aspects, and working times; therefore, it was not relevant to perform the L.E.S.T. evaluation

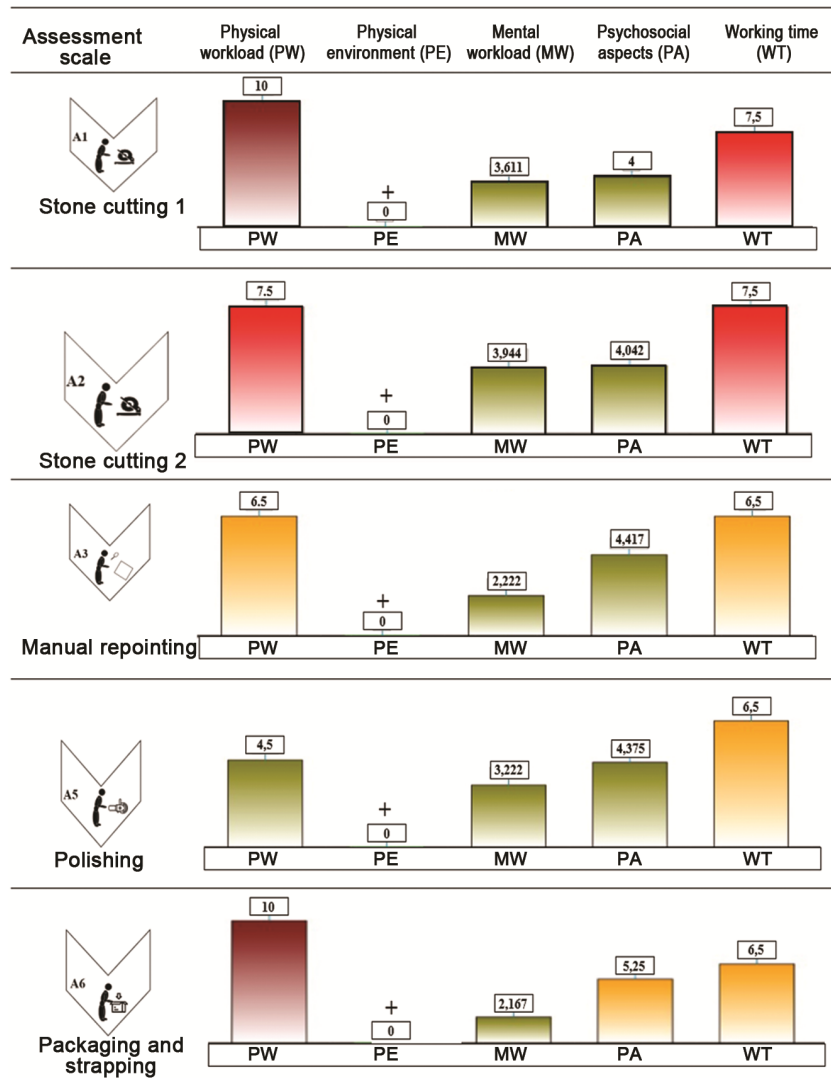


Fig. 6 — Evaluated areas and results obtained from LEST dimensions

the dimensions of physical load and working time for the stone cutting and polishing areas. Finally, the values of moderate discomfort (there is a risk of fatigue) are associated with the dimensions of physical load, working time, and psychosocial aspects in the areas of patching, parquet cutting, packing, and stone storage.

The results in Table 11 highlight that physical load, working time, and psychosocial aspects are factors that may impact the health of workers in the evaluated marble companies. With these results, decision-makers will consider the possibility of improving the working conditions in the evaluated areas.

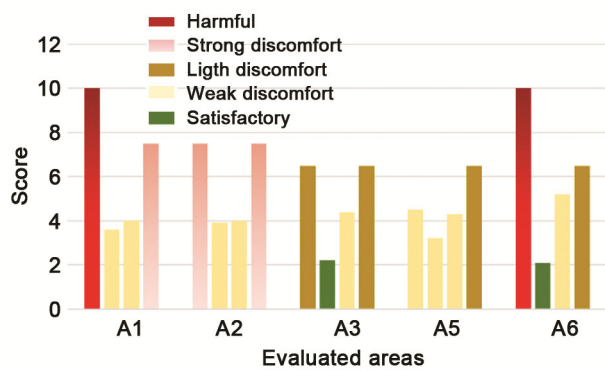


Fig. 7 — Summary of the areas evaluated using LEST general assessment

Correlation Analysis of LEST Factors in Workers of the Marble Industry

The principles of ergonomics, work psychology, climate theory, and organizational culture, and studies on time management suggest that the characteristics of work and the environment can influence physical load, mental load, psychosocial aspect, and working time, and that these variations may be correlated with the specific area where activities are carried out, arguing that the design of the workplace and the nature of the tasks can influence the physical demand on employees.³⁶⁻³⁸ With this in mind, Tables 12 and 13 present the Null Hypothesis (H0) and Alternative Hypothesis (H1). For each (H0), it is proposed that there is no significant correlation between the measured dimension and the area where the activities are conducted. That is, since the area has the appropriate working conditions for the worker's activities, any observed difference is attributable to chance. Conversely, for each (H1), it is proposed that there is a significant correlation between the dimension in question and the area where the activities are conducted, so the observed difference is not attributable to chance and there is a real relationship between the variables.

Particularly, the Chi-square statistical test (χ^2) using a contingency table^{39,40} allowed determining if

Table 11 — Evaluation matrix of LEST Factors

Area	V1	V2	V3
A1	Physical load	Working time	Tolerable
A2	Physical load	Working time	Tolerable
A3	Tolerable.	Tolerable	Working time
A5 [†]	Tolerable	Tolerable	Physical load, Working time
A6	Physical load	Tolerable	Working time, Psychosocial aspects

[†]Manual/Automatic | V1=Harmfulness | V2=Strong discomfort (Fatigue) | V3=Moderate discomfort (Risk of Fatigue)

Table 12 — Correlation analysis between work dimensions and work areas in the marble industry

Dimension	Hypothesis	Chi-square (χ^2)	Conclusion
I. Sleep Level	H0: There is no correlation between sleep level and the areas where work activities are performed	[†] $\chi^2 = 22.9608$	There is no significant correlation between sleep level and the areas where work activities are performed.
	H1: There is a correlation between sleep level and the areas where work activities are performed.	^{††} $\chi^2(\alpha, gl) = 32.6706$ $\alpha=0.05, gl = 21$	
II. Mixed demands Fatigue	H0: There is no correlation between mixed demands fatigue and the areas where work activities are performed.	[†] $\chi^2 = 8.2468$	There is no significant correlation between mixed demands fatigue and the areas where work activities are performed.
	H1: There is a correlation between mixed demands fatigue and the areas where work activities are performed.	^{††} $\chi^2(\alpha, gl) = 14.0671$ $\alpha=0.05, gl = 7$	
III. Mental demands Fatigue	H0: There is no correlation between mental demands fatigue and the areas where work activities are performed.	[†] $\chi^2 = 14.9119$	There is no significant correlation between mental demands fatigue and the areas where work activities are performed.
	H1: There is a correlation between mental demands fatigue and the areas where work activities are performed.	^{††} $\chi^2(\alpha, gl) = 23.4868$ $\alpha=0.005, gl = 14$	
IV. Physical demands Fatigue	H0: There is no correlation between physical demands fatigue and the areas where work activities are performed.	[†] $\chi^2 = 10.5536$	There is no significant correlation between physical demands fatigue and the areas where work activities are performed.
	H1: There is a correlation between physical demands fatigue and the areas where work activities are performed.	^{††} $\chi^2(\alpha, gl) = 23.4868$ $\alpha=0.005, gl = 14$	

[†] Chi-squared (χ^2) calculated | ^{††} Chi-squared (χ^2) statistic value | [†] $\chi^2(\alpha, gl)$; where $P(1-\alpha)$; $gl = (ri-1)(cj-1)$

Table 13 — Correlation analysis between work variables (LEST) and work areas

Dimension	Hypothesis	Test statistic (F)	Conclusion
Physical load	H0: There is no correlation between physical effort and the area where activities are performed	$\dagger F = 9.3903$	There is statistical evidence of a correlation between physical effort and the area where activities are performed
	H1: There is a correlation between physical effort and the area where activities are performed	$\dagger\dagger F(\alpha, v1, v2) = 2.7587$ $\alpha=0.05, v1 = 4, v2 = 25$	
Mental load	H0: There is no correlation between mental load and the area where activities are performed	$\dagger F = 7.6306$	There is statistical evidence of a correlation between mental load and the area where activities are performed
	H1: There is a correlation between mental load and the area where activities are performed	$\dagger\dagger F(\alpha, v1, v2) = 2.7587$ $\alpha = 0.05, v1 = 4, v2 = 25$	
Psychosocial aspect	H0: There is no correlation between the psychosocial aspect and the area where activities are performed	$\dagger F = 7.1123$	There is statistical evidence of a correlation between the psychosocial aspect and the area where activities are performed
	H1: There is a correlation between the psychosocial aspect and the area where activities are performed	$\dagger\dagger F(\alpha, v1, v2) = 3.2571$ $\alpha = 0.05, v1=4, v2 = 12$	
Working time	H0: There is no correlation between working time and the area where activities are performed	$\dagger F = 0.5102$	There is no statistical evidence of a correlation between working time and the area where activities are performed
	H1: There is a correlation between working time and the area where activities are performed	$\dagger\dagger F(\alpha, v1, v2) = 3.1791$ $\alpha = 0.05, v1 = 4, v2 = 13$	

\dagger Fisher (F) calculated | $\dagger\dagger$ Fisher (F) statistic value | $\dagger F(\alpha, v1, v2)$; where $P(1-\alpha)$; $v1 = (k-1)$, $v2=k(n-1)$

Table 14 — Correlation analysis and recommendations for working conditions in the marble industry

Dimension	Correlation with Work Area	Recommendations for the Marble Industry
Sleep level	Not significant	Establish reasonable working hours, promote healthy sleep habits; provide a work environment to prevent fatigue and improve productivity
Fatigue	Not significant	Include task rotation, scheduled breaks, and appropriate equipment to minimize physical strain; Design health and wellness programs addressing mental and physical fatigue
Physical load	Significant	Adopt automation of operations, use of physical load equipment, training in safe material handling techniques to minimize manual handling of heavy loads
Mental load	Significant	Training in Good Manufacturing Practices, establishing clear procedures; promote effective communication that fosters a collaborative and supportive work environment
Psychosocial aspect	Significant	Promote open communication and teamwork and encourage an open-door policy among different organizational levels
Working time	Not significant	Design reasonable work hours and schedules; propose adequate rest policies and provide opportunities for personal and professional development outside the workplace

there is a significant association between two categorical variables, based on the comparison between observed frequencies (what happens) and expected frequencies (what would be expected if there were no association). In this analysis, Table 12 describes the results of the evaluated dimensions, including the level of sleep and mixed, mental, and physical fatigue, in relation to areas A1, A2, A3, A4, and A5, where work activities, are conducted. The ANOVA, the F statistic, allowed identifying significant differences between the means of distinct groups.⁴¹ The dimensions "Physical Load", "Mental Load", and "Psychosocial Aspect" show a significant correlation with the work area, while "Working Time" does not show a significant correlation (Table 13).

The relationship between work dimensions and work areas in the marble industry is summarized in Table 14. Although sleep level and certain types of fatigue do not show a direct correlation with specific areas, they should be monitored for the benefit of health and work productivity. A significant

correlation is identified between physical load, mental load, and psychosocial aspect with work areas, highlighting the need to reduce these loads and promote a healthy work environment. There is no statistical evidence of a direct correlation with working time, but it is recommended to improve the workspace to ensure safety and well-being of health and work productivity. These recommendations provide a guide to improve working conditions in various industries.

Context of Labor Factors in the Marble Industry in Mexico

To analyze the labour context of the marble industry in the studied companies, the measurements of the evaluation of working conditions in marble companies are evidenced by contrasting them with records of disease and accident occurrences reported by the IMSS (as clarified on page 3, its meaning in 2021.⁽³¹⁾ The IMSS report states that only 3 out of 15 marble companies registered with the State Government of Puebla⁴² provide social security to

workers. This data is important because, according to the IMSS, the morbidity reported and associated with individuals affiliated with marble companies in 2020 showed acute respiratory infections, wounds and trauma, and pulmonary conditions (EPOC).³¹

The findings of this research, along with the IMSS report, show that the health of workers is potentially compromised in the medium and long term due to the activities of the marble industry in the study region. In this regard, generating and implementing actions to reduce risks, accidents, and occupational diseases remains a pending task in Mexico within these companies. These findings are common in other communities with similar traumas, showing that shared experiences can lead to similar outcomes in behaviour and effects. For example, in Turkey, the TRIZ methodology was applied in a marble company to reduce problems related to noise, lighting, and socio-ecological damage caused by marble waste and effluents.⁶ These authors report that the change strategies implemented in this Turkish community improved the quality and volume of marble transformation when low lighting problems were addressed; controlled high noise levels; and sustainably utilized waste and effluents. On the other hand, in Palestine, to address problems of accidents and occupational diseases⁷, they proposed creating public policies to achieve a balance between the industrial development of the marble sector and the well-being of the environment and ecosystems. Meanwhile, other studies³ have demonstrated that occupational risks can be prevented by implementing an occupational safety management system, risk prevention policy, and promoting worker participation in training programs and occupational health plans.

In Mexico^{13,43}, It has been reported that both the Comarca Lagunera region and the Mixteca zone of Puebla have raised concerns about damage to occupational health and ecosystems in regions where the industry operates. However, despite the recognition of health risks caused by waste from marble cutting and polishing⁴⁴, studies have only focused on proposing alternatives for utilizing this waste. This article contributes by highlighting the importance of factors such as lighting, noise, and operational conditions in the internal work areas of marble manufacturing.

Conclusions

In this research, the factors affecting working conditions in the cutting, polishing, storage, and shipping areas of two marble factories in Tepexi de

Rodríguez, Puebla, Mexico, have been identified and evaluated. On one hand, the findings highlight the parameters of Noise and Lighting in the Stone Cutting and Product Polishing areas as direct incidence factors of health damage to workers. Meanwhile, indirectly, the worker's perception of sleep quality index and work-related fatigue are the most significant factors affecting their performance quality and work productivity.

Future research could expand the sample size and randomly select more workers to model and simulate the dynamic system of this industry to explain the correlation of factors affecting working conditions and worker productivity in different areas of the company.

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