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Ergonomic intervention in the manufacturing process of chemicals in a company of the Petrogas / Sergipe network

A intervenção ergonômica no processo de fabricação de produtos químicos em uma empresa da Rede Petrogas, Sergipe

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Abstract: This paper presents a summary of the results of the project "LabErgon / UFS - A new network among university, business and society", focusing on ergonomic diagnosis and recommendations presented to improve working conditions in the productive process of one of the participating companies. The Laboratory of Ergonomics of the Department of Production Engineering of the Universidade Federal de Sergipe (LabErgon/ UFS) was implemented with the objective of developing studies aimed to the application of the Ergonomic Analysis of Work (AET) in companies of the state of Sergipe. Research on this subject is justified due to the organizations losses resulting from work accidents, occupational illnesses, absenteeism, dissatisfaction with work and other factors that reflect the employees' quality of life in low productivity and loss. It is an exploratory, applied research with a case study design. We carried out the mapping of the organization processes under study and the unfolding of the activities that make up the productive process, from which the analyzes of the organizational, technical and environmental work conditions were made. The most immobile dysfunctions were generated by the movements required in the execution of the activity (both regarding dislocations from the failed layout and postures and movements in the tasks) and by the unfavorable thermal environment. The results validate the research methodology adopted and the assumptions about the importance and necessity of ergonomic intervention in the companies of the oil and gas chain in the State of Sergipe.

Keywords: Ergonomics; Ergonomic work analysis; Work conditions; Health and safety at work.

Resumo: *Este trabalho apresenta um recorte dos resultados do projeto LabErgon/UFS – Uma nova Rede em Ergonomia entre Universidade-Empresas-Sociedade, focado no diagnóstico e recomendações ergonômicas apresentadas para melhoria das condições de trabalho no processo produtivo de uma das empresas participantes. O Laboratório de Ergonomia do Núcleo de Engenharia de Produção da Universidade Federal de Sergipe (LabErgon/UFS) foi implantado com o objetivo de desenvolver estudos voltados para a aplicação da Análise Ergonômica do Trabalho (AET) em empresas sergipanas. Justificam-se a realização de pesquisas sobre o tema em virtude das perdas para as organizações advindas dos acidentes de trabalho, doenças ocupacionais, absenteísmos, insatisfação com o trabalho e outros fatores que se refletem em baixa produtividade e prejuízo para a qualidade de vida dos colaboradores. Trata-se de uma pesquisa exploratória, aplicada e o delineamento adotado foi o estudo de caso. Realizou-se o mapeamento dos processos da organização em estudo e o desdobramento das atividades que compõem o processo produtivo, a partir das quais foram feitas as análises das condições organizacionais, técnicas e ambientais de trabalho. As disfunções mais insofismáveis foram geradas pelos movimentos exigidos na execução da atividade (tanto em relação a deslocamentos oriundos do leiaute falho quanto a posturas e movimentos nas tarefas) e pelo ambiente térmico desfavorável. Os resultados validam a metodologia de pesquisa adotada e os pressupostos da importância e necessidade de intervenção ergonômica nas empresas da cadeia de petróleo e gás no Estado de Sergipe.*

Palavras-chave: *Ergonomia; Análise ergonômica do trabalho; Condições de trabalho; Higiene e segurança no trabalho.*

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1 Introduction

Ergonomics is presented as a practice of transformation (whether through adaptation or conception) of situations and devices, therefore, it is a scientific module of an applied nature (Falzon, 2007). The practice participates in a fundamental methodological dimension of knowledge in ergonomics, where knowing how to manipulate defines a method of analysis, knowing to manipulate defines an intervention practice and manipulating in order to know defines a research methodology, thus outlining the assumptions of this science (Pizo & Menegon, 2010).

For the business environment, research on this subject is justified because of the losses to organizations that come from occupational accidents, occupational diseases, absenteeism, dissatisfaction with work and other factors. Those usually reflect in poor productivity and employees' lives. Research in ergonomics, in a specific laboratory, as well as investigating loss data for organizations, should focus on identifying the origins of the causes of deficiencies in business health. A detailed analysis of the environmental, technical, and organizational conditions and the behavior of the human being in the development of their activities is necessary (Silva, 2008).

According to Iida (2005), occupational accidents are analyzed by frequency of occurrence and a report with summary description of the same. The reports generally have little information on working conditions at the scene of the accident, and do not provide sufficient subsidies for these conditions to be improved. Ergonomics research can promote the dissemination of the benefits of applying best practices to the routine of workers and, consequently, in the global results of the organization and regions, under the approach of organizational innovation, resulting from the interaction between the teaching and research institution, and society. According to the OCDE (2005), an organizational innovation is the implementation of a new organizational method in the company's business practices, in the organization of its workplace or in its external relations, the proposal inserts in this context the Ergonomic Analysis of Work (AET).

Meeting these demands of society depends on the creation and dissemination of specific scientific knowledge, produced in general in the academic environment. Iida (2005) states that knowledge in ergonomics is generally generated through research conducted at universities and research institutes. This original knowledge is presented in congresses or published in periodicals, from there they spread to university education and sometimes to the media. From this point on, it becomes possible to reach companies and society in general, and then be used comprehensively in its goal: transform work situations.

Thus, for the effective participation of organizations, as teaching and research institutions, in the development of this area of knowledge, it becomes relevant to implement structures to support this purpose. The laboratory appears as an environment conducive to the exercise of the approaches advocated by Pizo & Menegon (2010): to know by manipulating, to manipulate in order to know and to know in order to manipulate. On the one hand, there is the theoretical and interdisciplinary scientific knowledge that represents the support of the ergonomic studies and, on the other, there are the dysfunctions in the work situations that require solutions from the point of view of Ergonomics.

It is in this perspective that the Laboratory of Ergonomics of the Department of Production Engineering of the Federal University of Sergipe - LabErgon/ UFS is inserted. This was implemented with the objective of developing studies aimed at the application of the Ergonomic Analysis of Work (AET) in companies od the state of Sergipe. LabErgon / UFS was created in 2008, in the context of the project "LABERGON/ UFS - A new network among university, business and society", with the support of the Research Support Foundation of the State of Sergipe (FAPITEC) (PIBITI) in the promotion of human and material resources for the implementation of the laboratory and the Brazilian Micro and Small Business Support Service (SEBRAE) and the Production Cooperation Network Chain of Petroleum and Gas in Sergipe (Rede Petrogas / SE) in supporting the actions of ergonomic intervention and dissemination of knowledge in ergonomics.

The emphasis of this project was on the expansion of LabErgon / UFS research activities to meet the needs of the new network in ergonomics that involves the elements Federal University of Sergipe (UFS), companies and society in general. The main goal was to offer scientific resources to the design and use of new technologies, equipment, tools and new managerial models for the improvement of the human conditions of work in the diverse productive processes of companies in the State of Sergipe. It is the formation of an interorganizational network, with the purpose of promoting the transfer of technology, favored through the alignment between the projects carried out in the university (knowledge producer) and the demands of the companies (users of knowledge). The general objective of this article is to present a summary of the results of this project, focusing on ergonomic diagnosis and recommendations presented to improve working conditions in the productive process of one of the participating companies.

They are developed as specific objectives of this research: to promote the alignment of research activities in Ergonomics between UFS and companies; Collaborate with the dissemination of knowledge in methods and techniques that favor good working conditions in Sergipe companies; Identify the specific technical knowledge required by organizations in the region and provide support that benefits Sergipe society.

The project "LabErgon / UFS - A new network in ergonomics between University - Business - Society" requires the use of the systemic approach. According to Dagnino (2002), the use of the systemic approach implies two basic tasks: the identification of the components of this network and the understanding of the most important causal interrelations between the parties, which allow the evaluation of the impact of changes that originate in a component, in other parts of the system and in the system. The other task is to understand the dynamics of the system. In addition to the structure of the components and relationships, the analysis of the forces that generate the behavior of the system is essential to show how different components and processes functionally interact, generating the system responses, and giving rise to new properties, that is, as the system adapts and transforms. The alignment of this network, due to the intersection of a connector element, should stimulate organizational innovation, problem solving and continuous improvement of products and processes.

Ergonomic intervention is a technology of practice that aims to modify the work situation to make it more appropriate for the people who work in it (Silva, 2008). In this way, the worker operates in good conditions, increasing productivity, bringing welfare and benefit to the company, the government and the whole society, also through the assistance of research and development institutions.

2 Research methodology

The population (or universe of the research) is made off of all Petrogas/SE Network companies, thus colaborating that they have the same characteristics defined for a particular study, specifically the ergonomic analysis of their environments and processes, totaling a number of 33 (Thirty-three) companies registered at the time of the research. The sample is non-probabilistic, of the accidental type, with random agents interested in the theme Ergonomics and was selected from among those companies with interest in promoting the best practices of the working conditions, occurred during meetings of the network in December 2008, Resulting in 4 (four) companies.

The dialectical method is what guides the projects of LabErgon / UFS. It is based on the dialectic proposed by Hegel, in which the contradictions are transcended giving rise to new contradictions that require a solution. According to Marconi & Lakatos (2010), the dialectical method is based on the analysis of phenomena through their reciprocal actions, the contradictions inherent in the phenomena and the dialectical change that occurs in nature and in society. For dialectics, facts are not analyzed as fixed objects, but always in transformation, so that the end of one process is always the beginning of another. On the other hand, the authors affirm that, for dialectics, both nature and society are composed of interdependent objects and phenomena. It is, therefore, a method of dynamic and totalizing interpretation of reality, used in qualitative research.

The approach to the problem is predominantly qualitative, appropriate to the need to understand the various situations around the object of the study of ergonomics. According to Bryaman (1989 apud Miguel, 2010), the characteristics of the qualitative research are: emphasis on the subjective interpretation of the individuals; Delineation of the context of the research environment; Unstructured approach; Multiple sources of evidence; Importance of the conception of organizational reality and; Proximity to the studied phenomenon.

Regarding the objectives, the research is classified as exploratory. This type of research, according to Gil (2010), aims to provide greater familiarity with the problem, in order to make it more explicit or to construct hypotheses. Data collection usually involves a bibliographical survey, interviews with people who have had practical experience in the subject, and analysis of examples that stimulate understanding.

As to nature, this research is an applied research, since it is focused on the acquisition of knowledge for application in a specific situation (Gil, 2010).

The design was the case study, which consists of the deep and exhaustive study of one or a few objects, so as to allow its wide and detailed knowledge (Gil, 2010). The purpose of choosing a case study is related to the research objectives.

Although the emphasis of the study is on application, the first step is characterized by the literature review on the proposed theme: bibliographic research. For Gil (2010), practically all academic research requires at some point the accomplishment of work that can be characterized as bibliographic research and this one is elaborated based on material already published, like books, magazines, newspapers, theses, dissertations, annals of Scientific and related events, whether available in printed form or via the Internet.

The instruments of data collection used were: systematic observation, in a team of researchers and in the real life of the workers, with the help of a photographic camera, chronometer and tape; Non-structured interviews; Measuring instruments for noise, luminosity, temperature, humidity and thermal stress; Symmetric, for measurements and anthropometric symmetries; ANTROPROJETO software, created at the Federal University of Juiz de Fora (UFJF) allows the determination of body dimentions from the knowledge of the stature of an individual; Floor of each company for analysis of production flow layout and information flow.

The methodology for data collection of the environmental variables noise, temperature, luminosity and humidity involved the taking of five measurements at each work station, with an interval of approximately ten minutes between each measurement, and the value obtained for analysis was the average of the three values (Excluding extremes).

In order to collect the variable Wet Globe Index - Globe Thermometer (IBUTG), the thermal stress meter was positioned at the height of the worker's trunk or, in the presence of a main source of heat, at the height of the most affected point, Twenty minutes to five minutes to stabilize the device, one measurement being taken per room.

These environmental variables are analyzed by comparing the indices obtained in field surveys with those indicated in national and international standards, appropriate for each variable.

The data collection for the jobs was done in the field research and was based on the methodology of the decomposition of the human-task system, which corresponds to a defined role, which includes instructions and procedures (what to do, when to do and How to do it) and means (where to do, what to do), to be occupied by a certain subject. It was considered as a workstation the location located within the production system, indicating the place where someone is placed to perform a certain task or function. The ergonomic study of the work station had three phases: demand analysis (definition of the problem to be studied, from the point of view of the various social actors involved); Analysis of the task (analysis of the environmental, technical and organizational conditions of work); Analysis of activities (analysis of human behaviors at work, be they gestural, informational or regulatory).

The data collection is related to the problem and the assumptions of the elements of the ergonomic study of the organizations participating in the study and aimed at obtaining elements so that the objectives of the diagnosis of the ergonomic conditions proposed in the research can be reached.

For the analysis and discussion of the results, the researchers interpreted and analyzed the data tabulated and organized in the previous stage. The analysis was done to meet the objectives of the research and to compare and compare data and evidence with the purpose of confirming or rejecting the hypotheses of solutions-problems.

3 Theoretical framework

Ergonomics is a scientific discipline of fundamental contribution to the improvement of working conditions.

> The word Ergonomics derives from the Greek Ergon [work] and nomos [norms, rules, laws]. It is a discipline oriented towards a systemic approach to all aspects of human activity. (ABERGO, 2014).

Ergonomics seeks two fundamental objectives: to produce knowledge about work, the conditions, and the relation of man to work and to formulate knowledge, tools and principles capable of rationally orienting the transformation of working conditions, with the aim of improving the man-work relationship (Abrahão & Pinho, 2002).

Ergonomics is a relatively recent discipline and over time has presented various definitions influenced by the view of ergonomists. In 2000, the International Association of Ergonomics (IEA) presented a definition that is an international reference, where Ergonomics is defined as a scientific discipline that aims at a fundamental understanding of the interactions between humans and other components of a system, and the A profession that applies theoretical principles, data, and methods with the aim of optimizing people's well-being and the overall performance of the systems.

In the same year, the Brazilian Association of Ergonomics (ABERGO) defined that ergonomics "Ergonomics aims to modify and adapt work systems and its activities to the characteristics, abilities and limitations of people seeking for efficiency, comfort and safe performance."

In Brazil, a Regulatory Norm in Ergonomics was created, established by Ordinance No. 3,214, of June 08, 1978 of the Ministry of Labor and Employment (MTE) (Brasil, 1978), NR17, which

> [...] aims to establish parameters that allow the adaptation of working conditions to the psychophysiological characteristics of workers so as to provide maximum comfort, safety and efficient performance. (Brasil, 2002, p. 12).

In the same norm, in art. 17, section 17.1.1, working conditions are defined as

> [...] aspects related to lifting, transporting and unloading materials, furniture, equipment and environmental conditions of the workplace, and to the organization of work itself. (Brasil, 2002, p. 14).

As for specialization, ergonomics has three areas: physical ergonomics, cognitive ergonomics, and organizational ergonomics. Physical ergonomics deals with the anatomical, anthropometric, physiological and biomechanical characteristics of the man in relation to the activity, observing work posture, object manipulation, repetitive movements, musculoskeletal problems, workstation layouts, health and safety. Cognitive ergonomics deals with mental processes such as memory, perception, reasoning, and motor responses in a human relationship and the components of the system, observing decision processes, specialized performance, human-machine interaction, human reliability, and professional stress. Organizational ergonomics deals with the optimization of sociotechnical systems, organizational structure, rules, and processes, where communication, collective management, work and schedule conception, community ergonomics and cooperative work are observed (IEA, 2000).

Currently, the most used methodology is the Ergonomic Analysis of Work (AET), which

> [...] seeks to study work not only in its explicit dimension (task), as defined by production engineering, but above all in its implicit dimension (activities), A characteristic of tacit knowledge of operational level personnel. (Santos, 2001, p. 90).

For Cockell (2005), AET is an intervention methodology where, through the analysis of the real activity of the workers, aiming to develop knowledge about how a man truly behaves while exercising his work, it is possible to intervene and correct factors that Lead to unwanted results.

Wisner (2004) states that AET is a methodological model of intervention and transformation capable of apprehending the complexity of the relationship between man and his work, without testing a chosen model a priori. Its initial basis was centered on gestural, information grouping, procedures adopted in the production system and in thought processes (Abrahão & Pinho, 2002).

3.1 The AET in the implicit dimension

> [...] considers the activity as a central element to operationalize the performance of production systems, aiming to achieve a stable functioning in quality and quantity. (Silva, 2008, p. 84).

The inadequacy of workplaces for workers is a social problem with a consequence for productivity, safety, and health. In this way, it is up to the ergonomist to implement actions that minimize the worker's health and safety risks, increasing self-esteem, productivity and minimizing economic losses in the region.

As stated, one of the components addressed by the AET is the analysis of the movements and postures adopted by the human being in the development of his work activities and one of the methods used by the Ergonomics for the postural analysis of the worker is the RULA (Rapid Upper Limb Assessment), developed by McAtamney & Corlett (1993), described as an ergonomic technique for individual analysis of posture, strength, and muscular action. The use of this technique includes the assignment of numerical indices referring to postures and movements at work. A higher index means seemingly higher levels of risk. However, a low index does not guarantee that the site is free of any ergonomic problems (Guimarães & Naveiro, 2004).

From the disposition, it is perceived that Ergonomics is an area of knowledge of interdisciplinary nature and applied nature. The interdisciplinary character means that Ergonomics relies on several areas of knowledge and the applied nature is configured in the adaptation of the work place and the environment to the characteristics and needs of the worker (Dul & Weerdmeester, 2004).

However, it is proposed to deepen the debate and defend the application of ergonomics from the point of view of transdisciplinarity. In this way, the study of the subject allows to approach the complexity of every organizational system, analyzing several phenomena that need approaches built by the practical convergence. A transdisciplinary approach to ergonomic concepts can be more easily discussed in terms of applications of research conducted in productive environments (Silva, 2008).

From the perspective of transdisciplinarity, the understanding of reality ascends to another level, taking on a more comprehensive and always open meaning for new processes. A transdisciplinary research, focused on the articulation of several references, aims to overcome the fragmented vision of the different areas of knowledge in which Ergonomics is based, providing a holistic approach necessary to the understanding of work situations and the formulation and validation of hypotheses for problem solutions.

4 Results and discussions

The Petroleum and Gas Production Cooperation Network Chain in Sergipe (Petrogas / SE Network) began to be structured in 2003, after a diagnosis of the chain. Coordinated by SEBRAE / SE and Petrobrás, since its foundation the network has sought to interact and integrate with other networks, seeking to strengthen and develop its activities and its associates. Currently the network is made up of institutions promoting innovation, universities, governments, large, medium, and small companies (Rede Petrogas, 2014).

The purpose of the network is to integrate its members into actions that foster the development of the oil and gas productive chain, stimulating the expansion, and opening of new ventures, as well as investment in strategic areas such as research and development and quality. In addition, the network seeks to promote the development of products and services with quality, safety, respect for the environment and social responsibility and the strengthening of companies (Rede Petrogas, 2014).

The company object of the applied research presented in this article is a chemical industry (mentioned in this work as Company 1), belonging to the Petrogas / SE Network, founded in 1993, whose activities involve the manufacture of various chemical products and the provision of application of chemicals (from itself or other organizations) in areas of oil exploration. Three employees of the company (the production assistant, the production operator, and the production manager) are actively involved in the situation under analysis, responsible for all product preparation activities. Mapping of the processes of the organization and the unfolding of the activities that compose the productive process were done, using the principles of 5W1H to detail the relevant information.

The Ergonomic Analysis of Work was applied to all sectors, however, this article represents a part of the study, presenting a critical stage of the product manufacturing process, which consists of the transport of liquid and solid raw materials to the production area, where they are deposited in a suction tank. Subsequently, with the aid of a pump, they are raised to a mixing tank. The process, called by "circulation" workers, involves the movement of the solution between the two tanks, by means of the periodic activation of the pump. After the time stipulated in the production order, a sample is taken and taken to the laboratory for physical-chemical quality control analysis.

4.1 Analysis of organizational working conditions

The assignment of functions is documented through service orders, which define the responsibilities and observations pertaining to the health, safety, and environment of each employee. There is no rotation of functions, so it is recommended to enrich the work based on this practice due to the improvements in the physical and organizational conditions of work, including: reduction of monotony and fatigue, increased motivation and satisfaction with work, greater commitment of the employee, professional recognition and learning of every organizational system.

The layout adopted is of the functional type and considering that it is the same employees who perform all the product preparation activities, the distribution of the sectors throughout the shed is inadequate, since it requires frequent movement of workers over relatively long distances. In addition, the flow diagram analysis, indicated in Figure 1, allowed us to identify that the adopted layout does not follow the sequence of production tasks.

An alternative is to perform a layout improvement to position the sectors according to the sequence of the flow of materials in production and to make adjacent areas of greater movement between them, such as the storage of cylinders with industrial water and the production area. This recommendation is outlined in Figure 2. Another alternative is to use mechanisms to reduce stress during material movements, such as the use of electric pallet trucks (shown in Figure 3).

4.2 Analysis of tasks and activities

From the point of view of the ergonomic analysis, a study of the movements performed by the operators, under the spectrum of occupational biomechanics, including the application of the Rapid Upper Limb Assessment (RULA) method and the Analysis of the Recommended Weight Limit by the NIOSHI

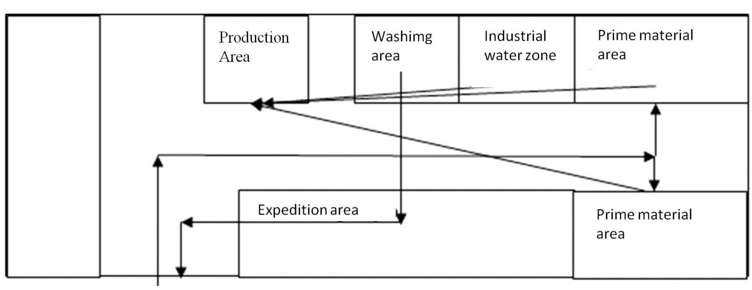

Figure 1. Flow diagram of the current production layout. Source: Own authorship.

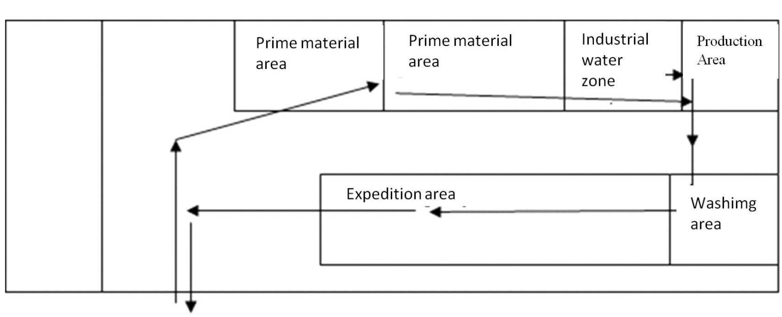

Figure 2. Flow diagram of the proposed layout. Source: Authors.

equation (National Institute for Occupational Safety and Health).

One critical step in the production process is the deposition of a solid feedstock (hereinafter referred to as MP01). This raw material is packed in bags of approximately 25 kg and is placed in piles on a pallet next to the suction tank. The production operator takes one sack of raw material at a time and rests it on the forearms. It does trunk rotation, spinal flexion and moves a few steps depending on the height of the pile and location of the bag. It is noteworthy that the official claimed to experience pain in the lower back in periods of intense production, where up to three batches of the product are produced per day. Next, lift the bag to the edge of the tank (89 cm high), flexing the upper limbs. Then, cut the end of the bag facing the inside of the tank with a knife and leave it bag vertically for descent of the product. Finally, place the empty bag in a waste container. This activity is shown in Figure 4.

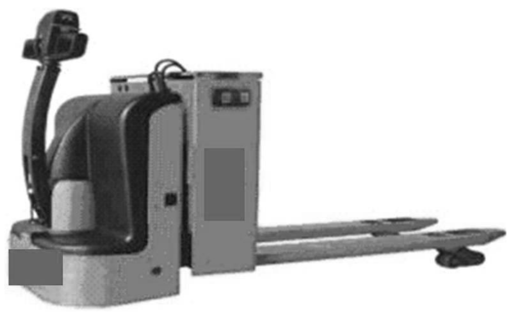

Figure 3. Electric trowel.

Figure 4. Operator performing the activity of deposition of the raw material. Source: Field survey.

This activity was analyzed using the RULA method. Figure 5 shows the scores selected according to the characteristics of the activities of the upper limbs and Figure 6 presents the results of the analysis of the movements and postures of the lower limbs, trunk, and neck. Table 1 describes the reasons for selecting the scores, according to the method's method.

A final score 7 was obtained, as presented in Figure 7, corresponding to a score of Level 4, which indicates that an investigation and immediate changes in the activity should be performed, taking as postures and movements considered critical: flexed arm approaching a plane perpendicular to the trunk at the level of the shoulder; Repetitive posture, load greater than ten kilos and trunk flexed almost to the horizontal.

The NIOSH equation was developed to calculate the recommended weight limit for repetitive load lifting tasks, such as the situation under analysis. The equation establishes a reference value of 23 kg, which corresponds to the lifting capacity, in the

Arm	Forearm	Wrist 1		Wrist 2		Wrist 3		Wrist 4	
		Wrist twist 1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	3	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	6	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Figure 5. Scores selected in the application of the RULA method for upper limbs (Group A). Source: Adapted from McAtamney & Corlett (1993).

Neck	Trunk 1		Trunk 2		Trunk 3		Trunk 4		Trunk 5		Trunk 6	
	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Figure 6. Scores selected in the application of the RULA method for lower limbs (Group B). Source: Adapted from McAtamney & Corlett (1993).

Table 1. Selection of scores in the application of the RULA method.

Aspect	Selected Score	Justification
Arm	3	Flexed arm approaching a plane perpendicular to the trunk at shoulder level
Forearm	2	Forearm flexion movement
Fist	1	Straight fist
Turn Fist	1	There is no wrist fist
Neck	1	Normal position
Trunk	5	Trunk flexed almost to the horizontal, there being also lateral flexion
Feet	1	Feet supported
Accruals	1	Repetitive posture
	3	Load greater than ten pounds

Source: Authors.

Final results A	Final results B 1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8	5	5	6	7	7	7	7

Figure 7. Determination of the final score in the application of the RULA method. Source: Adapted from McAtamney & Corlett (1993).

sagittal plane, of a height of 75 cm from the ground, for a vertical displacement of 25 cm, holding a load 25 cm from the body. This value is multiplied by six reduction factors, related to horizontal distance, height, vertical displacement, asymmetry, frequency, and grip. In the analyzed work conditions, it was calculated by means of the equation that the operator can lift approximately 10.85 kg without suffering musculoskeletal damages.

Based on these results, the methods for performing this activity need to be modified. The ergonomic risks that the task presents are related to weight lifting with the upper limbs, the repetitiveness of the task and the reduction in pile height throughout the activity. At the beginning of the activity the pile of sacks of the raw material is 87 cm, almost at the same level as the deposition tank (89 cm) and the height compatible with the reach of the standing worker without requiring flexion of the spine or lower limbs (The height of the standing elbow is 99 cm). In this situation, there is movement of the upper limbs and displacement around the pallet, if necessary. However, as the material is deposited, the height of the pile decreases, reaching a minimum of 20 cm, a critical posture used in the postural analysis by RULA.

Figure 8. Production Wizard performing manual mixing activity.

It is recommended to use a pallet lift mechanism that allows the operator to increase the height of the stack as he deposits the bags. Working heights should be such that the pallet and the edge of the tank are at the same level.

Another critical activity evaluated during the study was the manual mixing of the product in the suction tank, performed by the production assistant. While the raw material MP01 is deposited in the suction tank, the production assistant mixes the solution with a plastic stick, executes circular movements with the upper limbs counterclockwise, tilts the torso forward and rests on the right leg, slightly ahead of the left. It moves around the tank and periodically activates the pump, moving about two steps, extending the upper limbs, and activating the on / off switch with the fingertips. Figure 8 shows the accomplishment of this activity.

Like previous activities, this was also analyzed using the RULA method. Figure 9 and Figure 10 present the scores selected according to the characteristics of Group A (upper limbs) and Group B (lower limbs, trunk, and neck) activities, respectively. Table 2 describes the reasons for selecting the scores.

A final score 5 was obtained, as shown in Figure 11, corresponding to a Level 3 score, so that an investigation should be performed and changes should be performed in the short term, having as critical factors: arm flexion up to above of shoulder level and static posture. The activity is repetitive and the muscular effort required of the upper limbs increases according to the increase in the density of the solution being mixed.

The manual activity can be replaced by a mechanized agitator, according to the models shown in Figure 12.

Arm	Forearm	Wrist							
		1		2		3		4	
		Wrist twist							
		1	2	1	2	1	2	1	2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	3	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	6	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Figure 9. Scores selected in the application of the RULA method for upper limbs (Group A). Source: Adapted from McAtamney & Corlett (1993).

Neck	Trunk 1		Trunk 2		Trunk 3		Trunk 4		Trunk 5		Trunk 6	
	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Figure 10. Scores selected in the application of the RULA method for lower limbs (Group B). Source: Adapted from McAtamney & Corlett (1993).

Table 2. Selection of scores in the application of the RULA method.

Aspect	Selected score	Justification
Arm	4	Arm flexion up to shoulder level
Forearm	2	Forearm flexion
wrist	1	Wrist Extension
twist	1	There is no wrist twist
Neck	1	Lightly flexed neck
trunk	2	Little inflected trunk
Feet	2	Constantly lift one foot off the floor
Accruals	1	Static stance
	0	There are no loads

Source: Authors.

Final results A	Final results B 1	2	3	4	5	6	7+
1	1	2	3	3	4	5	5
2	2	2	3	4	4	5	5
3	3	3	3	4	4	5	6
4	3	3	3	4	5	6	6
5	4	4	4	5	6	7	7
6	4	4	5	6	6	7	7
7	5	5	6	6	7	7	7
8	5	5	6	7	7	7	7

Figure 11. Determination of the final score in the application of the RULA method. Source: Adapted from McAtamney & Corlett (1993).

Figure 12. Mechanical stirrers.

The suppliers of these equipment claim that these are normally sized specifically for each case and may be supplied with various ranges of power, rotation, rod length and propeller types and diameters, these settings being specified depending on the characteristics of the agitated product. The density and viscosity of the product to be agitated, in addition to the agitation type factor (homogenization, dissolution, solids suspension, etc.) directly influence the design of the equipment, and this information is essential for a good and efficient design of the equipment.

4.3 Analysis of environmental conditions of work

In the analysis of the environmental conditions of work, the diagnosis and recommendations regarding the thermal environment stand out. A series of factors present in the analyzed workplace favors the formation of a pleasant thermal situation: the shed is large, without partitions, has two wide doors arranged facing each other, there are no machines as a source of heat. However, the natural air circulation is not satisfactory, the clothing is relatively thick cotton, and the use of safety equipment (such as an apron and waterproof gloves) increases the thermal sensation. There is also an excess of sweat on the skin and in the clothes of the employees. These observations lead to consider the thermal environment unfavorable to the execution of the activities in terms of thermal comfort. Physical activities carried out in the heat cause the muscular capacity to be reduced, the yield decreases and the mental activity changes, presenting in the worker a disturbance of the sensorimotor coordination. The frequency of errors and accidents tends to increase, as the level of surveillance decreases, mainly from 30 °C (Iida, 2005).

To support the analysis, the IBUTG (Globe Thermometer Globe Index) was used, which serves as the basis for measuring occupational exposure to heat. Its measurement is performed by means of a stress meter. The metabolic expenditure found for the production operator indicates the existence of thermal overload because the IBUTG found (30.8) was higher than the tolerance limit (29.2). In order to reverse this situation, in addition to measures recommended to achieve a thermal comfort situation (such as the adoption of an artificial ventilation system), another practice is the relay of activities between the production assistant and the production operator, as well as the insertion of pauses throughout the process, which, according to NHO 06 (Occupational Hygiene Standard No. 06), for the temperature levels presented should be 15 minutes every 45 minutes. The adoption of ergonomic recommendations to adapt better work positions and reduce loads will also contribute to reduce the metabolic expenditure of both employees involved in the activity (FUNDACENTRO, 2002).

The lighting of the shed is made by means of natural light (by the presence of wide doors) and artificial (by means of suspended fluorescent lamps). The illumination is evenly distributed, with significant shading being noted only in the part of the shed behind the mixing tank due to the height of the tank. The digital display of the scale is in this region, but the presence of shade is favorable, as the values are bright and the presence of directed light could cause glare and difficult reading. The quantitative measurement indicated a mean illuminance at the workplace of 985.3 lx, an index above the parameters of ABNT NBR ISO / CIE 8995-1: 2013, which proposes that illuminance maintained in processing plants with constant manual work in chemical industries Is 500 lx (ABNT, 2013). It is possible to eliminate the excess of illuminance by fitting it to the indicated parameter, saving energy consumption, choosing less light bulbs, greater spacing, and sequences of luminaires with independent lighting, allowing them to receive higher Illuminance index only the areas of greatest demand.

There are two distinct acoustic situations that alternate at irregular intervals throughout the product preparation: with the pump on (72.9 dB) and the pump off (59.1 dB). The situation with the pump on shows a noise level higher than that indicated for acoustic comfort by the NR17: 65 dB. The recommendations are: position the pump on the outside of the shed, thus removing the source of noise, and adopt the use of ear protectors.

As for the handling of chemicals during production, a small amount of solid particulate is formed in the air during the deposition of the solid raw materials in the suction tank. In field research, we observed the use of nitrile rubber gloves, waterproof apron, waterproof boots, safety glasses and only by the production operator during the deposition of one of the raw materials, the use of respirator type air purifier Chemical filter with filter for acid gases. There is emergency shower and eye wash, as well as washing gloves and equipment that got in contact to the product. The use of face masks during the entire product preparation is indicated as recommendations, selecting the filter appropriate to the characteristics of the raw materials and the final product and wearing long-sleeved uniform.

5 Final considerations

The results validate the research methodology adopted and the assumptions about the importance and necessity of ergonomic intervention in the company. The importance is related to the minimization of the causes of workers' absence from work accidents, increasing their productivity and wellbeing in the organizational environment.

As results, it is noticed that the simplicity of the organizational structure and the interpersonal relations noticed resulted in the identification of few organizational deviations. The most immobile dysfunctions were generated by the movements required in the execution of the activity (both in relation to dislocations from the failed layout and postures and movements in the tasks) and by the unfavorable thermal environment.

Thus, the main recommendations were the use of equipment for transport and lifting of loads and for the realization of the mixture of solid and liquid components involved in the preparation of the product, to minimize the forces exerted by the workers in the execution of the activities and the Repetitive movements performed, which, in the long term, can cause lesions of musculoskeletal nature. Another recommended recommendation for priority treatment involves the installation of an artificial ventilation system and the promotion of rest intervals in order to minimize the consequences of exposure to inappropriate temperatures, considering the physical effort performed.

It is important to stress that the same type of investigation and intervention procedure was applied in all sectors of the organization, as well as in the other three companies that make up the scope of the project.

The application of the ergonomic recommendations derived from the ergonomic analysis of work aims to provide the worker with conditions that lead to a quality of life at work, which has close relations with the quality of life outside work. Acting on the worker, the cellular unit of an organization, favoring its better working position, takes, when together all the jobs of the organization, to an improvement of the productive system with consequence in a greater control on the process and reduction of failures.

It is also important to reduce the indexes of work-related accidents, absenteeism, and dissatisfaction with work, analyzing the financial losses resulting from these factors, as a resource to provide the financial health of the organization and the possibility of greater public investments and private in innovation of the productive systems.

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