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SAFETY MANAGEMENT MODEL BASED ON THE STANDARDIZATION OF PROCESSES AND 5S TO REDUCE THE RATE OF INTOXICATION IN SMEs IN THE CHEMICAL SECTOR

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Safety Management Model Based on the Standardization of Processes and 5S to Reduce the Rate of Intoxication in SMEs in the Chemical Sector

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Abstract. The chemical industry has showed steady growth in recent years and, as a result, the rate of intoxication has increased from the use of dangerous substances by employees of manufacturing companies. Therefore, small & medium enterprises (SMEs) in this industry must be committed to ensuring and guaranteeing safe and ergonomic workstations for employees that are mostly exposed to these risks to prevent incidents and reduce rates to a minimum when handling chemicals to produce paints and varnishes, and, at the same time, improve employee motivation and productivity. For this reason, this paper proposes the implementation of a safety management model based on process standardization and 5S for the purpose of promoting best practices in occupational safety and health, thereby reducing the number of intoxications within company grounds through employee collaboration in the improvement and optimization of working conditions, time management and resource use efficiency. This model is expected to achieve the reduction of intoxications by 40% after its implementation in a period of 10 months, furthermore, a series of simulations will be carried out to validate the results.

Keywords: process standardization, 5S, reduction of intoxications, chemical industry, occupational safety & health

1. Introduction

Global economic development depends on the growth and consolidation of key industries that allow other industries to flourish. One of them is the chemical industry, which is divided in two sectors, commodity, and specialty chemicals. In this sense, the former employs raw materials which are the basis for the products manufactured by the latter. These specialty chemicals are industrial products sold to companies such as paint and varnish manufacturers. Paint is basically composed of additives, solvents, binders, and pigments, which form a pasty substance [1]. Moreover, noticeable issues can be found in the environmental and occupational safety and health areas of industrial companies.

The most substantial concern recognized in chemical sectors is that occupational safety and health is not being considered as it should and, as a result, employee productivity is decreasing and generating additional costs, resulting in lower profitability [2]. Industrial chemical accidents include leaks, falls, fires, explosions, among others, although inhalation, skin contact, or ingestion of toxic chemicals remain as growing health hazards. Therefore, the presence of VOCs (Volatile Organic Compounds) can be found in companiesbelonging to the paint industry; these substances are present in the form of vapours [3]. For that reason, it is essential to implement mechanisms pertaining to the elimination or prevention of these risks. Likewise, workcan become a health promoter or a risk factor for employees since they spend more than a third of their day intheir workplace [4].

Regarding the problems that occur within the sector in question, tools are presented below that allow us to explain and propose a safety model with improvements based on process standardization and 5S. Firstly, the purpose of process standardization is the identification and evaluation of processes to align and improve times and thus establish better working conditions [5].

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Secondly, 5S philosophy and Lean thinking is mainly applied to optimize, increase efficiency, and reduce waste in processes, although it can also be used to improve safety within an organization by minimizing the accident rate [6].

Scientific literature review was carried out for this paper; case studies from companies in chemical sectors around the globe were contrasted to contribute with a new model to help manufacturers improve safety and health measures at work. This article contains six parts: Introduction, State of the Art, Contribution, Validation, Conclusions and References.

2. State of Art

2.1. The Importance of Safety in Companies in the Paint and Varnish Sector

After evaluating volatile compounds in the paint industry in Peru, scientists discovered risks of exposure to xylene and toluene are the most critical, due to their volumes of use, frequency of use and toxicity [7]. This discovery is closely related to the paper title since there are constant cases of accidents with the mentioned chemicals.

In addition, when talking about optimal working conditions for employees, personal protective equipment (PPE) play a vitally important role, the implementation of these should be emphasized as one of the measures to solve the problems referred to in the previous paragraph [8].

Furthermore, some consider leadership and safety to be closely related, mainly because an organization's commitment to safety is determined by its firm decision to dedicate resources to create an atmosphere that motivates employees to work safely [9].

2.2. Standardization of Processes in the Manufacturing Sector

The tri-conditional theory of safe behaviour indicates the need to focus on the adoption of safe work practices, this can be done through process standardization, incorporating an adequate sequence of processes, well established and structured [10]. In this sense, employees must receive training in standardized processes established by the company, ensuring safest and most optimal conditions are met.

Process optimization is done firstly through observation, measuring time and resources spent on each activity. These indicators can enable a safer workplace through the interpolation with the rate of accidents, developing a statistical relationship to facilitate the implementation of more effective measures. Normally, this tends to be time consuming, since all participants must be trained. Each observation lasts at least half an hour, meetings need to be held with employees, and measures implemented must be monitored accordingly [11].

For instance, after applying this methodology of process standardization based on operational safety, accident rate was reduced by approximately 28%, through the elimination of dangerous processes and generation of safer alternatives. To achieve this result, project managers conducted studies and informative workshops in the field [12].

2.3. 5S Methodology in the Manufacturing Sector

5S is a methodology composed of 5 steps: Sort, Set in Order, Shine, Standardize, Sustain. It is usually applied to increase productivity and establish a safe and organized workstation suitable for continuous production. Additionally, it helps reduce waste and optimize time utilization in the delivery of products or services [13]. For example, a paint manufacturing company in Saudi Arabia applied various lean tools: 5S, based on improving the organization of workspaces; SMED, focused on reducing processing times; process standardization, centred on enhancing process efficiency for employees; and the Kanban system, dedicated to control inventory, workflow, and cycle time optimization [14].

After application, materials were more accessible, thus reducing time per movement, minimizing task shifting cycles, decreasing the generation of defective products between processes, etc. [15]. Moreover, tools such as Value Stream Mapping (VMS) can also be applied to eliminate waste which does not contribute value to the final product, therefore reducing lead time from 8 and a half days to 6 days [16].

Following the presentation of case studies related to the application of 5S in manufacturing companies, the question arises whether this methodology can be refocused to improve occupational health and safety in the chemical industry.

In addition, the application of 5S to assist in the prevention and reduction of accidents is very recent, especially in Brazil [17]. Therefore, taking the decision to employ this methodology within a company can help promote safety and health in parallel to boosting the rate of productivity.

Consequently, lean principles can enhance outcomes from the application of 5S. For instance, an idea arose to design a system focused on management of near accidents related to processes involved in operating industrial machinery, which implicated the development of a pull design, obtaining satisfactory results from its use [18]. It can also be applied to behaviour-based security to increase the visibility of process data [19]. However, negative effects with lean approaches can take place such as minimizing the takt time, putting workers in higher risk conditions, among others [20].

The case studies of the implementation of the 5S methodology were based on the Plan, Do, Check, Act (PDCA) cycle, which enabled controlling of the main safety indicators. In this manner, training can be used to improve the learning curve of workers when applying this methodology.

3. Contribution

3.1. Basis of the Model

The proposed model presents the union of process standardization and 5S methodology. The latter aims to strengthen the corrections made from the optimization of processes to improve safety and order. In addition to refining the work environment, it will in turn bring more efficiency, eliminating waste in the process.

After carrying out the literature review, enough evidence was found in support of the possibility of reducing the intoxication rate with the construction of a model based on 5S methodology and process standardization for SMEs in the chemical sector.

Table 1: Comparative matrix vs. State of the art

Causes / **Article**	**Lack of use of Lean tools and methods for paint companies**	**Inadequate mapping of processes within the company**	**Deficient planning from company executives**
Melia, José [10]	Manufacturing based system for chemical industry applications	-	-
Martinez Oropeza, Ciro [15]	-	Occupational safety management	-
Montero Martinez, Ricardo [9]	-	Relationship between job safety and tools	-
Gomez Mojica, Julián [13]	Tools in chemical sectors	-	System planning based on chemical industry standards
Proposal	Chemical engineering tools	Chemical industry growth plans	Total production within the system

3.2. Proposed Model

As previously reported, 5S is focused on reducing waste and encouraging the participation of the workforce to generate engagement. Although it is applied to productive environments, it can also be used to improve the amount of commitment and teamwork, thus helping with accident reduction through the elimination of dangerous behaviors. In contrast, process standardization based on safety is a strategy focused on the implementation of a system of procedures to reduce time of exposure to hazardous chemicals which harm the safety and health of employees if contact is prolonged.

For the development of the proposed model, 5 phases were designed as shown in Figure 1.

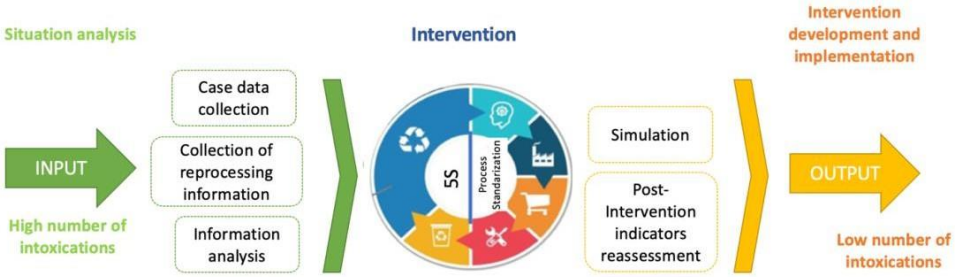

Fig. 1: Contribution tools.

3.3. Phases of the Model

Phase 0: Identification of the improvement aspect of the proposal (data collection)

Phase 0 consists of finding the production line with the most accidents. To carry out this phase, a small questionnaire was developed that allows us to know the most significant problems from the worker's perspective. It is important to analyze each part of the production process, however, it is also vital to make sure the workspace is on adequate conditions to be able to work efficiently.

Phase 1: Identification of tools and methods to be utilized

This phase consists of adapting process standardization and 5S to the problem identified, in this way, it will be easier to choose the tools and methods to use for the model. Firstly, process standardization is a way of relating occupational safety with reduction of times and production. This strategy has principles that are determined to motivate employees to carry out their work without presenting consequences of intoxication. Secondly, the 5S methodology basically means minimizing unsafe behaviors to prevent accidents. Part of this tool is the relationship that the employee has with order and organization of the workspace, and the materials he works with. However, this is not sufficient since it is also necessary to invest in training of the workforce within the company.

Phase 2: Dissemination of the Lean philosophy

Phase 2 consists of explaining to the workforce the importance of the goals proposed by lean philosophy. The lean objective is defined as a methodology based on the way of doing and especially of thinking. This means motivating employees to adequately perform their tasks, also to carry out their activities without generating waste or adapting new strategies to optimize times. Employees learning new methods generate greater efficiency.

Phase 3: Elaboration of the proposed tools

For this phase, a tool matrix was used that relates the objectives with the mentioned tool. The objectives are focused on the improvement of employee safety and workspace order.

Phase 4: Monitoring the results through indicators

In this phase, it is necessary to show results through KPIs that allow us to know to what extent progress has been made regarding the objectives set, based on the current situation. The indicators, formulas and objectives are shown as follows:

Accident rate due to intoxication in the process: With this indicator it is possible to calculate the trend of the number of intoxication accidents in relation to the total number of accidents that occur in the plant.

Objective: Reduce the poisoning accident rate to 20% or less.

$$\frac{Number\ of\ intoxication\ accidents}{Total\ accidents} x\ 100\% \quad (1)$$

Reprocessing rate: With this indicator you can calculate the increase or decrease in reprocesses that occur per batch produced.

Objective: Reduce the number of reprocesses by 25%.

$$\frac{Batches\ reprocessed}{Batches\ produced} x\ 100\% \quad (2)$$

Maintenance on the grinding machine: To find the indicator of this possible failure, it is necessary to measure how constantly a revision is carried out on the machine.

Objective: Carry out a preventive maintenance plan of the grinding machine once in two months.

$$\frac{Scheduled\ maintenance}{Total\ maintenance} x\ 100\% \quad (3)$$

4. Validation

4.1. Process Standardization Model

The developed proposal and simulated models are shown in this section. In the first place, the process standardization consists of adapting characteristics in a product or procedure, to reduce times, increase the productivity and efficiency of processes and workers. It is a quantitative method that consists of four steps that are the following:

- Division of the entire production cycle into different product lines.
- Division of the production lines.
- Evaluation of processes.
- Establishment of a procedure.

Of these four steps, the key is to establish an optimal and efficient procedure for the fabrication of products in companies in the chemical sector.

Table 2: Process monitoring responsible

PROCESSES	DESCRIPTION	RESPONSIBLE FOR MONITORING
Washing	The process is done in the same way	Operator 1
Weighing	The process is done in the same way	Operator 2
Grinding	The process is done in the same way	Operator 2
Quality control 1	The process is done in the same way	Operator 3

Addition	This step was separated from mixing	Operator 3
Mixing	This step was separated from the addition	Operator 4
Quality control 2	The process is done in the same way	Operator 3
Packing	The process is done in the same way	Operator 5
Packaging and labeling	The process will be automated	Operator 6 and 7

4.2. The Simulation of the Process Standardization Model

- Scope of the system: it is the step that represents in which part of the system we will focus with respect to the activities carried out for the process according to each company.
- Input variables: set the variables for the system. They can be presented this way:

Table 3: Established variables

Controlled variables	**Uncontrolled variables**
Working hours	Percentage of defective cans
Number of operators	Percentage of accidents
Number of cans produced	Demand
Time of exposure to aromatic compounds	Reprocessing time

- Sample size: A formula is used to find the optimal size of the model.
- System Entities - Shows System Entities, Attributes, and Components.
- System simulation model (See Figure 2).

To find the number of replications needed to validate the simulation, the Output Analyzer tool was used, in which the average and numerical operations are appreciated so that the simulation is significant.

Table 4: Current situation vs. Improved situation

Process	**AS IS**	**TO BE**	**OUTCOME**
Completion process standardization	36%	20%	44%
Work in parallel	74%	60%	14%

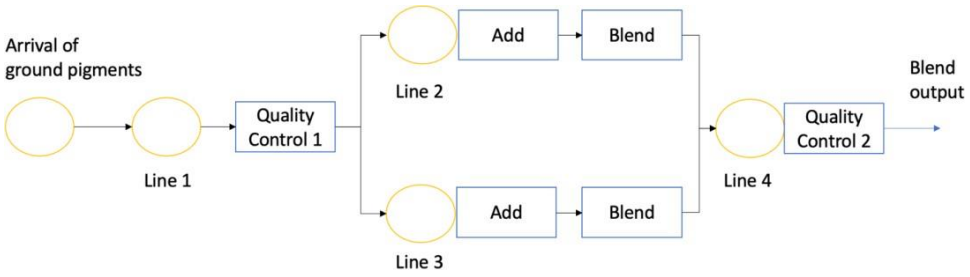

Fig. 2: Improved model.

5. Conclusions

5.1. Scenario 1

In this section, 5S implementation of the proposal with improvements for the company will be presented. In this sense, the indicators that were proposed for this type of tools and methods will be necessary.

Table 5: 5S indicators

Productivity indicators	Before 5S	After 5S	Percentage of improvement
Tool search time in seconds	14	6	42.86%
Equipment search time in seconds	8	3	37.50%
Gained space (clearance of zones) in m2	0	15	-

After the application of 5S in the company, it can be affirmed that, as a result, productivity has increased considerably at workstations, saving time while searching for materials and supplies. More space has also been gained in workspaces. Implementing these types of tools as a solution to the intoxication rate problem is positive in all aspects. For example, economically, the implementation costs are not significant, since tools that were already available in the company are used.

In conclusion, productivity increases considerably by more than 40% thanks to the implementation of the 5S methodology, since the search time for tools and supplies within the workstation is planned better, showing more order when considering the use of these inputs. For this reason, the implementation of this tool is very important, because it allows a better arrangement of workspaces.

5.2. Scenario 2

For this scenario, the new work standardization model will be evaluated as the efficient method to develop the tool.

Table 6: Process standardization indicators

Productivity indicators	Before Process Standardization	After Process Standardization	Percentage of improvement
Rate of exposure to toxic substances in workstations	25%	19%	24%
Rate of time within the system per operator	84%	67%	20.24%

Following the standardization of processes, the amount of time the operators spent within the system could be reduced and consequently the contact with hazardous substances was also diminished. This caused the number of intoxication incidents and accidents to be lower.

The level of intoxications in the company is directly proportional to the time in which the chemical inputs are manipulated to produce the gloss. Thus, with the implementation of process standardization in the completion stage, the time in which the operator remains within the production system will be reduced by 24%. Furthermore, the work of the operators can be optimized with this tool since activities are carried out in parallel.

It is important to emphasize that the implementation of these tools do not suppose significant expenses for the company, since the necessary resources already exist within the installations to be able to carry them out. The only factor missing from the equation is the decision from company managers to integrate this model to the ways of working.

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