

Implementation of Kaizen Methodologies to Reduce Waste and Promote Sustainability in a Paint Production Unit

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“Carpe diem, quam minimum credula postero”

Horácio

Abstract

In an increasingly demanding industrial landscape, the efficiency of production processes and the reduction of environmental impact have become essential factors for business competitiveness and sustainability. Within this context, Kaizen methodologies play a strategic role by promoting continuous improvement through standardisation, operator involvement, and the systematic elimination of waste. It was under this framework that the present project was developed at a paint production unit in CIN – Corporação Industrial do Norte, S.A., following the reconfiguration of the Central Hall, which had led to a significant increase in waste generation.

The project focused on the application of Kaizen methodologies such as 5S, SMED, and Standard Work to improve the efficiency of critical operations, including the washing of bead mills and fixed tanks, setup times in the dispersion area, and the organisation of operational spaces. The work was grounded in field observations, practical testing, workshops with operators, and the revision of internal standards. The interventions allowed for the definition of new consumption parameters, reduction of variability, improved process predictability, and the elimination of waste associated with disorganisation and the lack of operational criteria.

The results surpassed the initial objectives. Against the target of a 10% reduction in waste generation, savings of 23% in bead mill washings (14772 litres/year) and 31% in fixed tanks washings (75840 litres/year) were achieved, along with a reduction of approximately 300 hours/year in setup times. Beyond the operational and environmental gains, the project helped consolidate a culture of continuous improvement, standardisation, and shared responsibility, effectively integrating Kaizen principles with ESG pillars.

Implementação de Metodologias *Kaizen* para Redução de Resíduos e Promoção da Sustentabilidade numa Unidade Produtiva de Tintas

Resumo

Num panorama industrial cada vez mais exigente, a eficiência dos processos produtivos e a redução do impacto ambiental tornaram-se fatores essenciais para a competitividade e sustentabilidade das empresas. Neste contexto, as metodologias *Kaizen* desempenham um papel estratégico, promovendo a melhoria contínua através da normalização, do envolvimento dos operadores e da eliminação sistemática de desperdícios. Foi neste enquadramento que o presente projeto foi desenvolvido numa unidade de produção de tintas da CIN - Corporação Industrial do Norte, S.A., na sequência da reconfiguração da Nave Central, que tinha conduzido a um aumento significativo da geração de resíduos.

O projeto centrou-se na aplicação de metodologias *Kaizen* como o 5S, SMED e *Standard Work* para melhorar a eficiência de operações críticas, nomeadamente a lavagem de moinhos de esferas e tanques fixos, os tempos de preparação da área de dispersão e a organização dos espaços operacionais. O trabalho baseou-se em observações de campo, testes práticos, workshops com operadores e revisão de normas internas. As intervenções permitiram a definição de novos parâmetros de consumo, a redução da variabilidade, a melhoria da previsibilidade do processo e a eliminação de desperdícios associados à desorganização e à falta de critérios operacionais.

Os resultados ultrapassaram os objetivos iniciais. Face ao objetivo de uma redução de 10% na geração de resíduos, foram alcançadas poupanças de 23% nas lavagens dos moinhos de esferas (14772 litros/ano) e de 31% nas lavagens dos tanques fixos (75840 litros/ano), bem como uma redução de aproximadamente 300 horas/ano nos tempos de preparação. Para além dos ganhos operacionais e ambientais, o projeto ajudou a consolidar uma cultura de melhoria contínua, normalização e responsabilidade partilhada, integrando eficazmente os princípios *Kaizen* com os pilares ESG.

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Acronyms

CIN	Corporação Industrial do Norte, S.A.
ESG	Environmental, Social and Governance
FO	Filling Order
LO	Labelling Order
MO	Manufacturing Order
MTO	Make-to-Order
MTS	Make-to-Stock
NCP	Non-Conforming Product
PDCA	Plan Do Check Act
R&D	Research and Development
SMED	Single Minute Exchange of Die
SO	Shop Order
TPS	Toyota Production System
VSM	Value Stream Mapping

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1 Introduction

The current dissertation project represents the final outcome of the Master's degree in Mechanical Engineering at the Faculty of Engineering of the University of Porto. This project, entitled Implementation of Kaizen Methodologies to Reduce Waste and Promote Sustainability in a Paint Production Unit, was conducted in an industrial environment at CIN – Corporação Industrial do Norte, S.A. The project, which lasted four months, was developed within the Operations Department, with a focus on the recently renovated Central Hall (C1).

Within this context, the project was developed to explore and address the root causes behind the increasing levels of waste generation observed in Central Hall. The initiative focused on identifying the main sources of waste and implementing structured improvement actions to support both environmental and operational sustainability.

This chapter begins by providing context for the project and presenting the company. It then presents the project goals and the selected approach, followed by a discussion of the dissertation's structure.

1.1 Project Motivation and Background

In the current industrial landscape, sustainability has become a key concern for organisations seeking to balance economic growth with environmental responsibilities. Reducing the environmental impact of operations is no longer considered an optional initiative but rather a strategic priority that enhances efficiency, brand reputation, and compliance with increasingly demanding regulations. In this context, the application of continuous improvement methodologies plays a crucial role in aligning operational performance with sustainability goals.

At CIN, this mentality has been particularly relevant following the recent complete remodelling of the Central Hall, one of the company's main production areas. The upgrade involved the integration of new equipment and layout changes, as well as the production of a new range of products, which represented a significant transformation in the factory's operations. However, as with many industrial transitions, the aftermath of this change presented new challenges.

Faced with these challenges, this project was developed with a central objective: to identify and understand the causes of the increase in waste generation and to propose and implement improvements that would contribute to the optimisation and stabilisation of operations in the sector.

To this end, the project was based on Kaizen methodologies, focusing on continuous and incremental improvements involving the manufacturing team. Key tools, such as 5S, Standard Work, and SMED, were applied to improve workplace organisation, reduce variability, and shorten setup times, thereby contributing directly to reducing waste generation and supporting the company's broader sustainability objectives.

1.2 Company Presentation

Founded in 1917 under Companhia Industrial do Norte, CIN is a century-old Portuguese company that rebuilt itself in 1926 under the name CIN – Corporação Industrial do Norte, Lda. CIN has been leading the paint and varnish market in Portugal since 1992 and on the Iberian Peninsula since 1995.

Over its history, CIN has expanded the group by acquiring or founding new companies and by developing a distinctive brand for every one of its existing ones. CIN consistently seeks growth in markets where its strategic vision helps it become a leader and in areas where investments are justified.

Currently running 10 manufacturing units and 8 R&D facilities and laboratories across France, Angola, Mozambique, Spain, and its headquarters in Portugal (Figure 1), where this project is being carried out. Through its R&D facilities, CIN serves as a cornerstone of innovation by consistently anticipating market trends and analysing its competitors. CIN has thus not only gained respect in Europe, where it now ranks tenth, but also managed to rank thirty-third among the top coatings companies worldwide.



Figure 1 – CIN Headquarters

1.2.1 Business Areas

The company concentrates in four business units:

Architectural coatings (58%) – applied in the building sector, most especially in homes, apartment buildings, stores and warehouses. Professionals can make use of these products since they are extensively accessible thanks to a large network of distributors.

Protective coatings (12%) – high-performance coatings designed to shield metal or concrete structures like bridges, stadiums, petrol stations, wind turbines, and industrial sites, even in maritime, chemical, and urban environments.

Industrial coatings (23%) – liquid or powder coatings applied in industrial facilities to finish aluminium window frames, garage doors, outdoor, garden, and office furniture, and packaging for cosmetics, gas bottles, residential appliances, and transportation.

Yachting and marine (7%) – quality coatings for use in all marine applications, meeting the needs of both big shipyards developing ambitious yacht projects and enthusiasts of pleasure vessels.



Figure 2 – The different CIN's business areas

1.2.2 CIN Headquarters

Located in Maia, the Portuguese plant, shown in Appendix A, that produces most of the CIN group's products has six different halls: the raw materials warehouse (C0), where the separation of products for the other six halls takes place; the Central Hall (C1), where this project was developed, responsible for the general line of products; Novaqua (C2), which produces water-based paints; the varnish production unit (C4); the diluent production unit (C5); the mortar and bitumen unit (C6); and the industrial range production unit (C8).

1.3 Project Objectives

To address the increase in waste generation observed following the recent remodelling and operational transformation, objectives were established to be achieved in this project. To this end, the key objectives at the start were:

- Develop and implement structured improvements focusing on stabilising processes and optimising resources;
- Reduce waste generation by 10%;
- Task Standardisation;
- Promote a more efficient, sustainable and consistent working model across the production area.

The achievement of the established objectives will be supported by the implementation of Kaizen Methodologies, such as, 5S, Standard Work and SMED.

1.4 Adopted Methodology

To ensure the effective achievement of the project objectives, a structured, phased methodology was adopted in line with the principles of continuous improvement. The approach involved the following steps:

- Current Situation Analysis: Familiarisation with the Central Hall and its processes to identify the main problems and sources of waste. This phase involved collecting relevant data, facts, and direct observations to gain an understanding of the actual situation.
- Definition of Objectives: Clear and achievable objectives were established that were aligned with the previously identified problems and focused on reducing waste generation and improving process efficiency.
- Improvement Opportunities Identification: Determine possible solutions or countermeasures to address the root causes of inefficiencies and excessive waste. This involved reviewing practices, contacting operators, and analysing their potential impact.

- **Improvements Implementation:** Execute proposed solutions through process standardisation, applying the SMED methodology, and reinforcing the 5S principles to improve organisation, efficiency, and consistency across workstations.
- **Results Analysis:** Evaluate the results of the implemented improvements, including a comparison of times and costs before and after the intervention. Where necessary, adjustments were made to ensure the changes were effective and sustainable.

1.5 Structure of the Dissertation

This dissertation is divided into five chapters.

The first chapter begins with an overview of the project, presenting the company, outlining the project's objectives and describing the adopted methodology as well as the structure of the dissertation.

The second chapter provides the theoretical background that supports the project, focusing on Lean and Kaizen methodologies, relevant tools such as 5S, SMED and Standard Work, as well as the integration of sustainability and ESG principles in industrial settings.

The third chapter details the current state of the Central Hall, identifying the main inefficiencies, sources of waste, and contextual factors that led to the need for improvement.

The fourth chapter presents the development and implementation of the proposed improvements, as well as the results achieved following the application of the selected tools and standardisation measures.

Finally, the fifth and last chapter summarises the key conclusions and discusses the impact of the project.

2 Literature Review

This chapter presents the theoretical framework that supports the development of this project. It explores the principles and concepts of Lean Manufacturing, with particular emphasis on the philosophy of Kaizen and its related tools, which are widely used in industrial continuous improvement initiatives.

Additionally, this chapter discusses the ESG (Environmental, Social, and Governance) framework, which serves as a strategic foundation for evaluating corporate sustainability. The connection between ESG and Lean principles is also explored, as both share a focus on waste reduction, efficiency, and long-term value creation. This review aims to provide a solid theoretical basis for the improvements analysed and implemented in the following chapters.

2.1 Lean Manufacturing

Lean manufacturing originated in Japan following World War II. After suffering the consequences of war, the nation confronted a critical lack of resources, damaged infrastructure, and an economic crisis. The nation's industrial sector faced substantial challenges in obtaining financial resources, raw materials, and modern technological skills. This condition negatively impacted the nation's capacity to compete with major American automobile manufacturers, such as Ford and General Motors, which had established a robust presence in the market through their mass production methodologies (Ohno, 1988).

During this period, Toyota Motor Company, established in 1937, achieved a level of worldwide competitiveness. However, the mass production paradigm that dominated the era ultimately proved to be an inappropriate model for Toyota. This paradigm requires substantial production facilities, elevated costs, and consistent, predictable demand, none of which were available in the Japanese market (Womack et al., 1990).

Under this theory, Taiichi Ohno and Eiji Toyoda set out to create a manufacturing system capable of running effectively in a setting of limited resources and unpredictable demand. Their visit to Ford's American manufacturing plants motivated them to realise that the mass production model was insufficient to fit the particular requirements of the Japanese automotive sector. They thus aimed to design a flexible and efficient system able to generate limited quantities depending on current demand (Ohno, 1988).

Ohno realised that waste, or *Muda* in Japanese, was the root cause of mass production's problems. Most of the time and effort at factories, he observed, went towards procedures that added little to the final result. Among these activities were too high inventory, too much material transportation, and waiting for the next operations. Furthermore, this awareness formed the foundation for the creation of the Toyota Production System (TPS) (Liker, 2004).

According to Ohno (1988), the primary objective of the Toyota System Production is to improve production efficiency by systematically eliminating waste. This comprehensive approach to waste reduction aims to deliver the highest quality products at the lowest possible cost and in the shortest lead time. The system is supported by two foundational pillars: Just-in-time and *Jidoka*, represented in Figure 3.

Just-in-time (JIT) aims to minimise unnecessary delays by manufacturing goods and services in the required quantities at a specific time. The visual production control tool known as the Kanban system efficiently logs work to match demand, therefore facilitating JIT (Ohno, 1988).

Jidoka (Autonomy) is the capacity of machines and operators to be automatically identified and stopped in the case of problems, therefore guaranteeing quality from the start and preventing a rise in defects (Shingo, 1989).

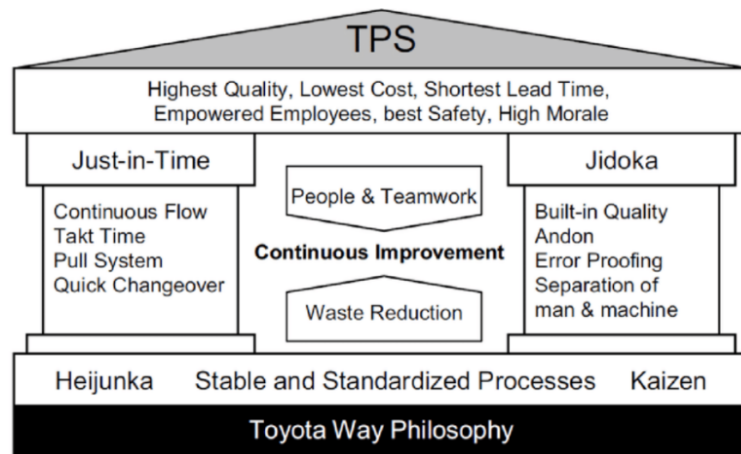


Figure 3 – The Toyota Production System House (Source: Liker, 2004)

Moreover, the TPS embraced the Kaizen (continuous improvement) idea, which includes all collaborators in the waste identification and elimination process, thereby promoting a culture of continuous improvement (Imai, 1986).

2.1.1 Lean Principles

Value

Lean's fundamental principle is to identify value from the viewpoint of the consumer. The consumer's willingness to pay defines value, so anything that contradicts this is considered wasteful. Emphasising value allows companies to ensure that every phase of the manufacturing process advances the customer and to reduce unnecessary processes. This concept helps businesses to fit their operations to the needs of their consumers, therefore promoting loyalty and satisfaction (Womack & Jones, 1996).

Value Stream

Value stream is the process of identifying and illustrating every stage required to obtain a good or service from beginning to delivery. This instrument helps companies to spot regions of waste and areas needing process development. By using value stream mapping, companies can clear obstacles, reduce delays, and boost operational effectiveness. It is a good way to understand the present situation of operations and design a future state that reduces waste and maximises value (Rother & Shook, 1999).

Flow

The flow principle's main goal is to guarantee that, free from obstacles or delays, work moves smoothly through the manufacturing process. Maintaining a constant flow of value calls for the clearing of obstacles, smaller batch sizes, and methodical process coordination. Establishing a flow facilitates the smooth transition of products from one step to the next, thereby reducing lead times and enhancing customer demand responsiveness. Moreover, a satisfactory flow reduces the possibility of flaws and inventory build-up (Ohno, 1988).

Pull

Contrary to the traditional technique of manufacturing based on forecasts, the pull principle is concentrated on the creation of goods and services just in line with the actual needs of customers. In push systems, the system drives products based on forecasts, while in pull systems, consumers directly place orders. Adoption of pull systems has been demonstrated to produce a decrease in overproduction, a minimisation of inventory costs, and an improvement

of resource use efficiency. Pull systems sometimes include tools like Kanban, which helps to enable a more flexible and responsive manufacturing process (Ohno, 1988).

Perfection

The last and fifth Lean principle is the pursuit of excellence. It underlines continuous improvement (kaizen) as a means of constantly trying to reduce waste and raise value. Perfection is a path along which companies continuously attempt to enhance procedures, goods, and services; it is not a destination in and of itself. Companies may adjust to changing market conditions, innovate more successfully, and keep a competitive edge over time by encouraging a culture of continual growth (Womack & Jones, 1996).

2.1.2 7 Mudas

Under the lean manufacturing paradigm, the idea of waste, also known as *muda*, refers to any activity or resource use that, from the customer's point of view, does not add value to the finished good or service.

In his pioneering study on the Toyota Production System, Ohno (1988) noted seven main types of waste (Figure 4) that compromise flow and efficiency. Achieving operational excellence and continuous improvement depends on identifying and removing these wastes (Liker, 2004).

1. **Overproduction:** when goods are manufactured either before they are needed or in quantities that exceed the actual demand of consumers. As a result, overproduction leads to extra inventory, unnecessary storage, and hidden flaws. This kind of waste is regarded as the worst since it usually covers or causes other inefficiencies (Ohno, 1988).
2. **Waiting:** idle time caused by machine faults, limited material availability, or uneven workloads.
3. **Transportation:** unnecessarily moving supplies or items between places. While some transportation is inevitable, too much of it raises the likelihood of damage, energy consumption, and running expenses (Melton, 2005). Monden (1998) claims that optimising the layout and cutting the time between process phases is the best approach to solving this issue.
4. **Overprocessing:** the result of processes requiring more work or more accuracy than is suitable. Usually, the causes are inadequate process planning, antiquated product designs, or a lack of consumer attention (Shingo, 1989).
5. **Inventory:** an excess of materials, work in progress, or finished products that exceed the needs for manufacturing. Ohno (1988) claims that inventory acts as a buffer that conceals problems instead of resolving them. Excessive inventory immobilises capital, consumes space and leads to product obsolescence. (Liker & Meier, 2006).
6. **Motion:** any unnecessary activity performed by workers that does not contribute to the end result, such as excessive walking, reaching for tools, or repositioning items. Imai (1986) stresses the need for ergonomic office design and Gemba observations in pointing out these inefficiencies.
7. **Defects:** when goods do not meet established quality criteria. Apart from lower customer satisfaction and higher running expenses, this results in additional handling, lost resources and delayed deliveries. Shingo (1989) asserts that prevention outperforms detection, necessitating the development of methods that eliminate the risk of failure at its source. Liker and Meier (2006) emphasise that quality has to be developed through standardised processes and error-proofing techniques if we are to avoid recurring quality problems and guarantee process dependability.

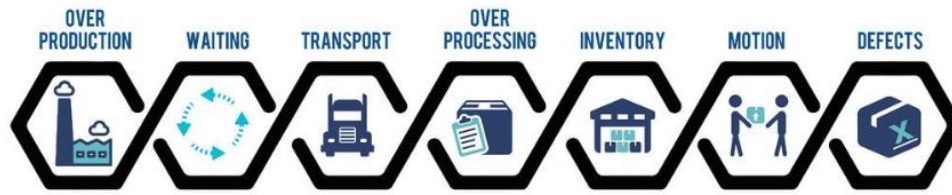


Figure 4 – The 7 wastes of Lean (Source: gembaconcepts.com)

2.2 Kaizen

Originating from the Toyota Production System (TPS), the Japanese word Kaizen - derived from "Kai" (change) and "Zen" (good) - translates as "change for the better" or continuous improvement. The idea first became well-known when Masaaki Imai established the Kaizen Institute in 1985. Imai defines Kaizen as the ongoing development of one's personal life, social contacts, and professional procedures (Ohno, 1988).

Kaizen is not only a collection of tools or isolated projects but a comprehensive management philosophy based on the conviction that regular, little changes motivated by the participation of all employees can create a long-term competitive advantage (Liker, 2004). Kaizen emphasises tiny, low-cost changes that are done consistently and methodically, unlike innovation, which sometimes calls for significant investments and disruptive changes (Ohno, 1988).

Kaizen's primary goals are to eliminate waste, improve quality, and raise operational efficiency by means of methodical problem solving and employee involvement. By pointing out inefficiencies and suggesting fixes, it empowers employees at all levels to help improve processes. This inclusive strategy promotes discipline, responsibility, and ownership, among others (Shingo, 1989)

Several Lean technologies practically support Kaizen, enabling the methodical implementation of its ideas in industrial environments. These instruments support waste identification, standardisation efforts, and ongoing cultural education. Among the most often applied are the PDCA cycle, Visual Management, Process Mapping, the 5S method, Standard Work, SMED, and VSM. These tools, which will be covered in the following subchapters, are essentially practical enablers of the Kaizen principle and help Lean companies to integrate continuous improvement into their daily operations.

2.2.1 PDCA Cycle

Designed by W. Edwards Deming, the PDCA (Plan-Do-Check-Act) cycle is a fundamental tool for applying the Kaizen philosophy—that is, a methodical strategy to improve manufacturing processes by combining problem identification and action implementation.

Four stages constitute this cycle (Figure 5). Plan is the first step; it is the recognition of an opportunity or problem, followed by an examination of root causes and a design of action for development or change. The Do phase consists of carrying out, under limited scope, the previously defined actions. The Check phase emphasises examining the outcomes of the modifications that were carried out and assessing whether they have produced the expected results. At last, the Act step is implementing the knowledge gained from the past levels. If the implemented activities yield the desired results, standardise them for the benefit of other change initiatives. Otherwise, start a fresh cycle and arrange more suitable actions (Lodgaard, Gamme, & Aasland, 2013).

Using the PDCA cycle as a method of problem-solving has advantages since the model is, by nature, simple. Its methodical approach helps teams to understand and use it with little need for in-depth training or prior debate (Stern, 2017).

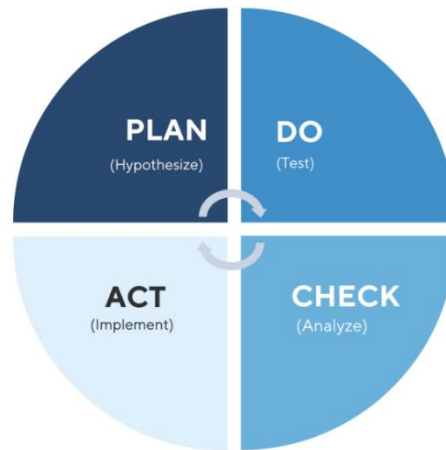


Figure 5 – PDCA Cycle (Source: productplan.com)

2.2.2 Visual Management

Lean-based visual management uses simple visual signals to show important information, thereby increasing stakeholder knowledge. Its main objectives are to remove obstacles to communication and improve office information flow. To promote openness, efficiency, and clarity, we should make visual systems readily understandable and globally accessible (Singh & Kumar, 2021).

Many additional Lean tools, such as standard work, 5S and Process Mapping, are built upon this concept. Hall (1987) defines this approach as communication without words or voice since he underlines the importance of quick, simple, globally accessible visual management strategies for information distribution. Visual work instructions, floor markings, information boards and *andons* (Figure 6) make up the most common visual management systems. These instruments seek to enable employees to control their work environment and improve the process visibility. Visual systems display the present level of activity, thereby supporting standard commitment, helping to eliminate various types of waste, and reducing errors (Oliveira, Sá, and Fernandes, 2017).



Figure 6 – Example of an *Andon*

2.2.3 Process Mapping

Process Mapping is a visual management technique that shows the sequence of activities, decisions and interactions within a process. It is essential for lean manufacturing and continuous improvement, as it helps teams to see how work moves through a system and identify inefficiencies and opportunities to reduce waste (Melton, 2005).

Among the different types of process maps, swimlane diagrams provide a disciplined approach to showing complex processes involving several functional areas or stakeholders. In a swimlane diagram, activities are organised into lanes, each representing a department, job role, or responsibility entity. This structure makes it easy to understand one's obligations and the flow of interactions across the company (Marchwinski et al., 2008).

In Lean and Kaizen environments, this tool is often the first step in improvement projects. By clarifying the current condition, it makes root cause analysis possible and prepares the ground for more advanced tools, including Standard Work, SMED and 5S.

2.2.4 5S

Hiroyuki Hirano established and released the 5S methodology as a methodical framework for visual management, standardisation, and workplace organisation. Designed to increase operational efficiency and cut waste, the five Japanese concepts - Seiri (sort), Seiton (set in order), Seiso (shine), Seiketsu (standardise), and Shitsuke (sustain)—together make the 5S technique (Figure 7). Lean implementation and continuous improvement in many fields start with these ideas (Michalska & Szewieczek, 2007):

Sort

This is the first “S” and involves eliminating unnecessary items from the workstation and keeping just those necessary for the current project. The process removes distractions, sharpens focus, and reveals previously missed inefficiencies.

Set in order

Symbolises the intentional, ergonomic arrangement of necessary tools and supplies in a systematic way, increasing the efficiency of access and return. By using visual management tools, this approach has shown to be successful in lowering search time and raising workflow efficiency.

Shine

Frequent cleaning of the workplace and equipment, not only to provide a pleasant environment but also to uncover abnormalities such as leaks, wear, or damage before they grow into major difficulties.

Standardise

Development of standardised routines, visual controls, and consistent policies to maintain the first three-phase benefits. It implies the constant developing of standards and the strengthening of training all throughout the company's operation.

Sustain

Development of a disciplined culture based on ongoing conformity with established standards. The method calls for a constant dedication shown by frequent audits, leadership support, and staff involvement.



Figure 7 – The Five Steps of 5S (Source: menda.descoindustries.com)

2.2.5 Standard Work

Standard work, an essential lean technique, defines and notes the most effective, safe, and consistent method of performing a given work. It reduces operator variations, provides the basis for consistent procedures, and increases continuous improvement. Standard work helps develop a consistent workflow by defining an optimal sequence for operations, expected durations, and necessary inventory, thereby matching it with customer demand (Team, 2002).

Standard work usually involves three main elements:

- Takt Time: the time required to complete a task at the client's requested speed.
- Standard Work Sequence: outlines the exact order in which tasks are to be performed, which is important for efficiency and accuracy.
- Standard Work-in-progress: the minimum amount of inventory required to maintain continuous processes. (Team, 2002)

Standard work will help manufacturing and service companies as much as it will help others. Reducing process variation raises the quality of goods and services while lowering the possibility of mistakes. Giving new operators clear, consistent instructions guarantees faster integration, accelerates their learning process, and makes training easier. It maximises work processes and eliminates pointless stages or delays, thereby raising efficiency. Including best

practices in regular activities lowers the likelihood of mistakes and dangerous behaviour, therefore enhancing safety. It provides a strong, quantifiable basis for projects aiming to achieve continuous improvement.

2.2.6 SMED

Designed by Shigeo Shingo, the Single-Minute Exchange of Die (SMED) approach seeks to decrease equipment changeover time. It aims to cut setup time to under ten minutes, allowing smaller batch sizes, faster demand response, and more manufacturing flexibility (Shingo, 1985). By removing non-value-adding operations and lowering product preparation times, SMED supports lean manufacturing in the competitive environment of today, where responsiveness and efficiency are absolutely vital (Kumar et al., 2020).

Shingo classified setup operations into two categories (Ulutas, 2011):

- Internal Setup – operation that can only be performed when the machine is shut down;
- External Setup – an operation that can be carried out while the machine is still running.

In general, SMED implementation consists of three basic phases: differentiate between internal and external configurations once the whole process has been designed. Identification of inefficiencies and improvement of regions depend on this classification. Internal configurations then must be converted to external ones. Once this conversion is complete, the final step is to simplify and optimise the remaining tasks (Ulutas, 2011).

2.2.7 VSM

Value Stream Mapping (VSM) is a very important Lean tool that helps companies see, analyse, and rethink the flow of activities from raw materials to finished products and information across the value stream of a good or service. It promotes the creation of strategies to reduce waste and increase lead time, and it helps spot both value-adding and non-value-adding steps in processes (Hines & Rich, 1997).

By highlighting inefficiencies such as excess inventory, needless transportation, delays, and inadequate information flow, VMS actually encourages continuous improvement (Oliveira, Sá, and Fernandes, 2017).

2.3 ESG

Strategic system Environmental, Social, and Governance (ESG) is used to examine the non-financial performance of companies and therefore evaluate their management of responsibilities with respect to the environment, society, and internal governance systems. ESG's core goal is to direct businesses towards ethical and sustainable solutions that strike a balance between long-term value creation for stakeholders, including investors, workers, consumers, and the larger society (Linnenluecke, 2022).

Three linked pillars form the ESG framework (Radzi et al., 2023):

Environmental (E): the set of actions taken by the company to protect the environment by focusing on low carbon emissions, waste management, energy efficiency, sustainable water use, preservation of biodiversity, and slowing of climate change. This pillar evaluates the degree to which the company reduces the environmental effect of its industrial activities.

Social (S): focuses on the way the company handles its contacts with both internal and outside stakeholders. It addresses elements including consumer happiness, data privacy, gender equality, and diversity; employee involvement; human rights; and labour norms. Socially

conscious businesses typically have more credibility and legitimacy among stakeholders, as Radzi et al. (2023) note.

Governance (G): relates to the way the company is run. It covers things like the board of directors' makeup, policies against corruption, executive compensation, political contributions policy, whistleblowing systems, and open financial reporting. Effective government lowers information risk and builds investor trust.

ESG has been especially relevant in the industrial sector as companies try to strike a balance between operational effectiveness and regulatory compliance and stakeholder expectations. Adopting ESG values helps companies improve reputation, increase access to financing, and reduce long-term risks connected to social conflict or environmental impact (Linnenluecke, 2022).

Additionally explored in the framework of environmental performance is the interaction between ESG and Lean. Lean techniques, such as eliminating waste, standardising processes, and optimising flow, can serve as practical drivers for achieving environmental goals, according to Dues et al. (2013). Lean's integration with ESG concepts, especially those pertaining to the environmental pillar, might improve sustainability results even though it does not naturally solve all environmental issues. The writers do, however, also recognise certain trade-offs, such as higher transportation needs in Just-in-Time systems, which would run counter to goals for emissions reduction. The argument highlights the importance of aligning lean strategies with ESG priorities to avoid unnecessary environmental impacts (Dües et al., 2013).

Lean and Kaizen methodologies also help ESG theoretically and operationally by offering ways to increase resource efficiency (E), include staff members in continuous improvement (S), and improve process transparency and control (G) (Shen, 2023). ESG thus specifies the "what" in terms of sustainability goals; Lean and Kaizen provide the "how" in terms of execution.



Figure 8 – The three pillars of ESG

3 Problem Description

The first section of this chapter provides a detailed description of the paint production process, with a particular focus on the Central Hall. Understanding how the different phases are interconnected is essential for identifying the root causes of inefficiency and recognising the impact that each operation can have on the final product.

Following this, a comprehensive analysis of the current situation is presented, focusing on areas affected by disorganisation, lack of standardisation, and excessive waste generation. This diagnostic phase aims to identify clear improvement opportunities, which are subsequently addressed through the Kaizen methodologies outlined in Chapter 4.

3.1 Production Process

The paint production process in the C1 sector is defined by two basic processes: manufacturing and filling. During manufacturing, raw materials are turned into an intermediate product which, after the filling process, results in the final product. A process map was created to record the entire process, from order placement to product delivery. Included in Appendix B, the map illustrates the interactions between all the involved activities and stakeholders, as well as their historical sequence. The following sections will provide a detailed overview of each aspect.

This company uses two production techniques: Make-to-Stock (MTS) and Make-to-Order (MTO). The MTS system produces goods in advance based on inventory levels and sales forecasts, storing them as needed, thereby predicting demand. In contrast, the MTO system follows specific customer orders or requests to adjust the colour of a stock product.

Following an analysis of demand and customer orders, the production planning stage begins. The first step is to process the Shop Order (SO), resulting in two documents: the Manufacturing Order (MO) and the Filling Order (FO). Once generated, these documents are printed and follow separate but parallel workflows within the production system until they meet again in the filling process.

At this stage, the availability of the required raw materials is verified. Once confirmed, the materials are reserved in the system. Subsequently, on the following day ($n+1$), the Raw Materials Warehouse defines which solid and liquid raw materials need to be separated and prepared for manufacturing.

Following this, liquid raw materials are sent in whole units, in barrels or cubes, via the logistics train, on day $n+1$. In the specific case of sector C1, liquid raw materials are stored in sector S10, which is a dedicated area within C1 designed specifically for storage and weighing, as shown in Figure 9. Therefore, the raw materials warehouse only sends liquid raw materials when the required components are not available in S10. In parallel, frequently used bulk liquids are stored in silos and can be automatically delivered in precise quantities straight to inline weighing systems or dispersers via specially designed pipes. On day $n+1$, an operator weighs the liquid raw materials in S10 and then transports them to the raw materials supply area in C1, where they are kept on standby.



Figure 9 – Storage and weighing area for liquid raw materials in S10

On the other hand, the solid raw materials are weighed in sector S7, on day $n+1$, which is exclusively designated for this task. Once all the solids have been weighed, an internal logistics train transports them on pallets, on day $n+2$, along a defined route through all the manufacturing sectors. Upon arrival at C1, the materials are placed in the supply area of that sector, where they remain on standby until the manufacturing process begins.

The manufacturing process is then carried out, on day $n+2$, by closely following the instructions provided in the MO, which works like a recipe. This specifies each of the raw materials involved, their exact quantities, and the sequence of the operations to be performed, as well as their execution times. The process then moves to the pre-mixing stage; in which case a disperser assists to combine the components. The established objectives will determine whether this process is carried out through homogenisation or dispersion. The primary objective of this stage is to break down solid particles in the fluid medium to ensure a homogeneous and stable distribution. In addition to outlining the sequence in which the raw materials are added, the MO specifies the dispersion speed for each stage and the duration of the dispersion process.

In some formulations, the particle size obtained from dispersion is not enough to satisfy the intended product performance. In such cases, the mixture is subjected to a second refining stage, called grinding. Bead mills perform this processing by passing the paint through a chamber filled with microbeads. The shearing and impact forces produced by the revolving components and beads together break down agglomerates to produce a finer and homogeneous particle dispersion. However, grinding is not a required step in every paint-making process.

Once the required particle size has been achieved, the process moves on to the final stage. The remaining liquid raw components are then added to the mixture to provide the product its last characteristics. If necessary, a colour adjustment is executed to ensure that the final colour aligns with the established requirements. This step can be accomplished either manually or automatically through the Colormix system.

After completing the process, the operator collects a sample and sends it, along with the MO, to the Laboratory of Quality Control (LCQ). There, tests are carried out to ensure that the product meets the stated requirements before filling. The test results suggest one of three possible outcomes:

1. Approved: the product is ready for filling;
2. Rejected: the product does not comply with the specifications and cannot be sold – Non-Conforming Product (NCP);
3. Requires correction: the product must be corrected before being retested.

In parallel, the labelling sector operates based on a document called the Labelling Order (LO), which is printed in that same sector. This document specifies all the information required to print the product labels and carry out the labelling process. Once the labels are ready, the process can either go to labelling, if required, or advance directly to the material separation phase. In this step, the LO is stapled to the FO and are sent to the warehouse L or A, where all the necessary packaging materials are gathered and prepared for filling.

Finally, the sector provisioner assembles the packaging materials, the MO and the FO, and the labels in preparation for the start of the filling process. Once this is complete, the pallets are strapped and transported to the dock, from where they are sent to the Distribution Centre.

3.1.1 Manufacturing

Sector C1 organises the manufacturing process into two distinct types, each designed to handle different batch sizes and operational requirements. The first is small-volume production, which is carried out in mobile tanks with a capacity of up to 1200 litres. The operators manually transport these tanks through the several phases of manufacturing until they reach the filling stage. The second method involves large-volume production, where four large dispersers perform the manufacturing automatically.

These dispersers are located on an elevated platform where solid raw materials are supplied by a freight elevator and added manually by operators. Bulk liquid raw materials are delivered in precise quantities straight to the dispersers via specially designed pipes, while those stored in barrels or cubes are connected through hoses positioned below the tanks, allowing the dispersers to draw the liquid into them, as shown in Figure 10.



Figure 10 – Introduction of liquid raw materials

Appendix C illustrates the relationship between the different tanks and the production lines, showing the layout of the fixed tank area. As can be seen, the tanks are positioned in line, making it possible to understand the flow and connection between each stage of the process.

DPHSD 06, 07 and 08 are smaller-capacity dispersers, each with an associated intermediate tank (IBT 05, 06, and 07, respectively). Tanks BT11 to BT22 are responsible for finalising the products.

DP-21 is a high-capacity disperser used for higher-volume production. It has two intermediate tanks (IBT 08 and IBT 09) that feed final tanks BT 23 and BT 24.

On the same platform, there are fixed intermediate tanks used to store the product after its initial processing in the dispersers. Product can be transferred directly from the disperser to the intermediate tank through hoses. When grinding is necessary, the disperser is connected to a bead mill located under the platform and connected to the intermediate tank. During the transfer, the product passes through the mill, which grinds it as it stores.

After the intermediate tanks, the product is transferred to the final tanks, where manual finishing adjustments are carried out by operators. The finished product can then be filled directly into one of the six filling machines located next to the tanks.

In small-volume manufacturing, production takes place in smaller dispersers, presented in Figure 11, where both solids and liquids raw materials are added manually by the operators.



Figure 11 – Small-volume disperser

Once dispersion is complete, mobile tanks are transported by forklift either to the grinding area if required or directly to the agitators for product finishing.

When grinding is necessary, the operators manually connect the tanks to the bead mills and initiate the grinding process. The tanks are then placed in the agitators, where the final raw materials are added manually to give the product its final form. Once approved, these batches are then moved to the filling stage, which is carried out in ME-39 or manually using a dedicated filling platform designed specifically for this type of operation. The mobile tank is positioned

above the containers, allowing the product to be filled by gravity, as illustrated in Figure 12, without the use of pumps, unlike the other filling machines.



Figure 12 – Manual Filling

3.2 Analysis of the Current Situation

Section 3.1 provided a comprehensive overview of the production process, offering the context needed to understand how problems can arise in the system. In the paint industry, even slight delays or disorganisation in certain operations can result in significant amounts of waste, increased costs, or safety issues. Therefore, a detailed understanding of the process flow is crucial for identifying where such issues are most likely to arise.

The following subchapters address each of the identified problems individually, examining their causes and implications in detail. These findings will later form the basis of the Kaizen-based improvement measures proposed and implemented in Chapter 4.

3.2.1 Workspace Disorganisation

As mentioned in Chapter 2.2.4, the 5S concept, derived from Lean and Kaizen methodologies, emphasises the importance of maintaining a clean, organised, and clearly structured working environment. As well as being organised, it is important that the workspace has a simple and visible system for identifying materials and zones. This clarity directly contributes to the efficiency of regular operations by enabling workers to quickly locate tools and resources, thereby reducing delays and confusion. It also supports the onboarding of new employees by making production flows easier to understand.

In contrast to these principles, organisational and ergonomic issues were identified during the initial observation phase, particularly in two key areas: the mobile tank storage zone and the dispersion area. Both of these areas play a critical role in the production process, yet their current layout revealed issues that contributed to delays, reduced efficiency and limited visibility of materials, highlighting the need for improved layout structure and standardisation.

The mobile tank storage area is used as a temporary holding area for the mobile tanks. Despite the distinct status of each tank, the area lacked any form of structured organisation or visual separation, as seen in Figure 13. Tanks were often placed randomly in close proximity to each other, frequently requiring one tank to be moved to access another. The disorganised layout meant that it was not always possible to identify the tanks correctly, as their small identification labels could easily be obscured when a tank was surrounded or partially covered by others. This increased the time taken to locate the correct tank and introduced unnecessary movement and handling. Additionally, the lack of visibility of the outlet valves made it difficult to detect potential leaks, presenting a risk to safety and cleanliness in the area.



Figure 13 – Current situation in mobile tank storage area

The dispersion area also had major organisational issues, as seen in Figure 14. Essential items, such as cleaning materials, mobile cleaning tanks, and waste collection bins, had no defined location. This lack of organisation made the space difficult to navigate and manage. The area was often found to be dirty and disorganised, with tools and materials scattered around, which resulted in setup delays and inefficiencies, as well as increased ergonomic strain for operators.

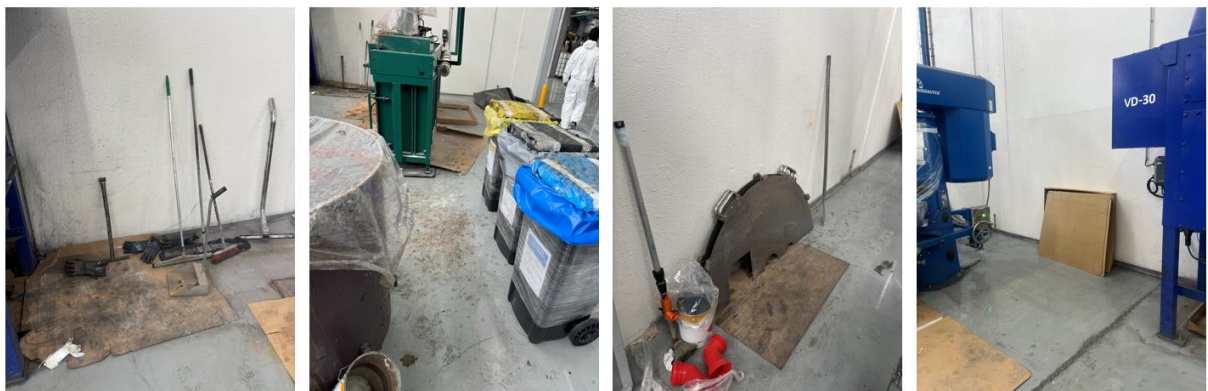


Figure 14 – Current situation in dispersion area

Additionally, the use of a support trolley (Figure 15) during the bead mills washing process raised a safety concern. Operators use the cart to transport heavy containers of solvent or water for cleaning the bead mill. Towards the end of the cleaning process, when the container was almost empty, operators often had to tilt it to extract the remaining liquid. However, due to the lack of functional brakes or stabilisers on the cart, this movement would cause it to slide or shift suddenly, creating a real risk of the container falling. In such situations, there was a risk of the container landing on the operator's feet or legs, which could result in injury.



Figure 15 – Grinding support trolley

These issues demonstrate a significant deviation from the principles of 5S. The combination of poor layout, disorganisation and a lack of cleanliness has compromised both operational performance and worker safety, highlighting the need for targeted improvements.

3.2.2 Disperser Cleaning and Preparation Setup

Between each dispersion process, the operator must thoroughly clean the disperser to prepare it for the next batch. This setup includes all steps performed from the moment the previous tank is removed until the next batch can begin.

During the first months, the setups were observed not only to identify each step involved but also to understand the most efficient method and sequence for executing them. These observations were recorded using a sequence chart, shown in Appendix D, enabling a detailed analysis of the operations and the time spent on each step.

The analysis of the observed setups revealed significant variability in their duration. Each setup involves several different movements and difficulties in cleaning the dispersers, which naturally led to different execution times. Figure 16 displays the times obtained for each setup.

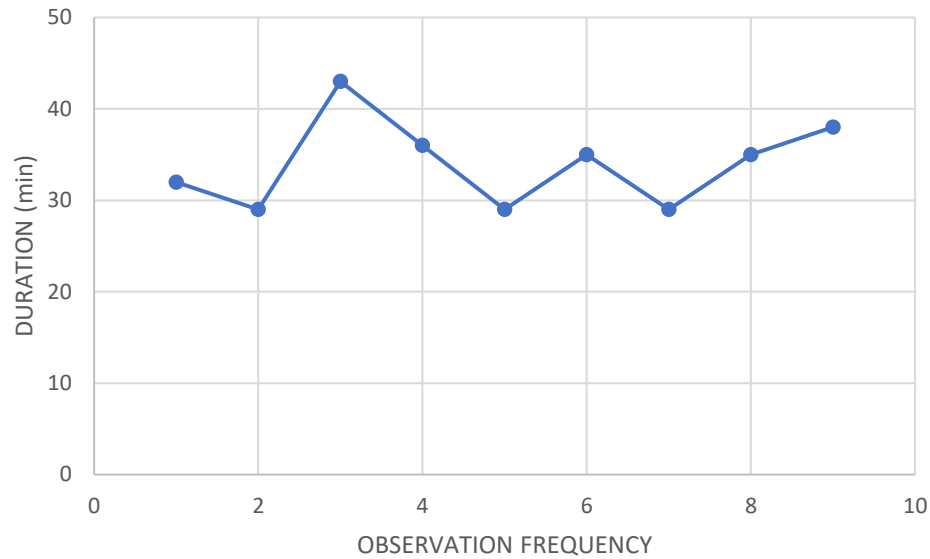


Figure 16 – Distribution of setup times

The data collected throughout the observations indicated that the average setup time was approximately 34 minutes, which is relatively high for a routine process that occurs frequently.

Several factors, including the disorganisation of the workspace as described in the previous subchapter, drove this inconsistency in setup time. The absence of predefined storage and preparation prior to setup meant that operators often started the process without having all the necessary materials and tools to hand (Figure 17).

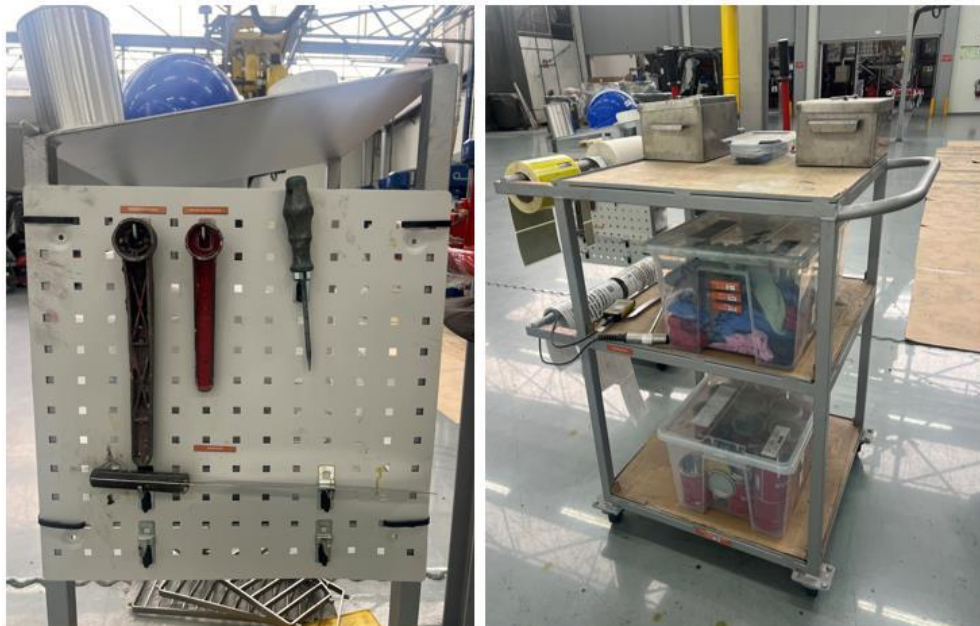


Figure 17 – Tools and materials used during dispersion

As a result, it became clear that it was necessary to define the ideal sequence of operations, organise the space, and ensure that operators are prepared in advance. Given the recurrence of this type of setup, it was selected for a SMED analysis, which is detailed in Subchapter 4.2, where targeted measures are proposed to streamline the process and reduce waste.

3.2.3 Bead Mills

One of the first processes analysed in detail was the washing of the small-volume bead mills, which takes place between grinding operations whenever a product change occurs.

The washing procedure varies depending on the nature of the following product. If the nature of the product remains the same (e.g., changing from a solvent-based product to another solvent-based product or from a water-based product to another water-based product), only one type of cleaning agent (solvent or water, as appropriate) needs to be used.

However, if the nature of the product changes (e.g., changing from a solvent-based product to a water-based product or vice versa), the process becomes more complex, involving the use of three different cleaning agents in sequence:

1. The agent corresponding to the previous product;
2. An intermediate aqueous solution;
3. Finally, the agent corresponding to the next product.

In both cases, the entire volume of the cleaning agent used becomes waste. Therefore, introducing any excess during the process directly increases waste generation, with associated environmental and economic implications.

To understand the quantities used in bead mill washing, a document was adapted, as seen in Appendix E, for operators to record the quantities they used in each wash.

One of the most obvious problems was that operators were not following the specified quantities for each type of wash. In fact, they consistently used much larger quantities of solvent or water than indicated in the associated standard for this process. Further analysis revealed that this behaviour resulted not from negligence but from a misalignment between the established standards and the current operational conditions.

The specified quantities in the standard were no longer sufficient to ensure effective washing, especially under the current operational context, which has changed due to modifications in both the production facility and the range of products manufactured.

As the defined quantities proved unreliable, each operator began to rely on their own judgement, resulting in a wide discrepancy in the quantities used. The amount of cleaning agent used varied greatly depending on the operator's experience and perception of risk. This operator-dependent approach led to a significant increase in waste generation.

Besides this, it became clear that the recorded values rarely reflected the actual quantities used. The containers used to transport the cleaning agent were not weighed, and there was no way to quantify the amount added. Consequently, operators estimated volumes based on habit or perception, but these estimates were consistently inaccurate. In some cases, operators believed they were using a certain volume, but in practice, the amount added to the mill was significantly different.

In order to obtain a clear and objective understanding of the quantities used in mill washing operations, a set of washings was observed and measured directly. In each case, the operators weighed the amount of cleaning agent used. Figure 18 shows the quantities measured for each wash when just one cleaning agent was used, and Figure 19 shows the quantities measured for each change-of-nature wash.

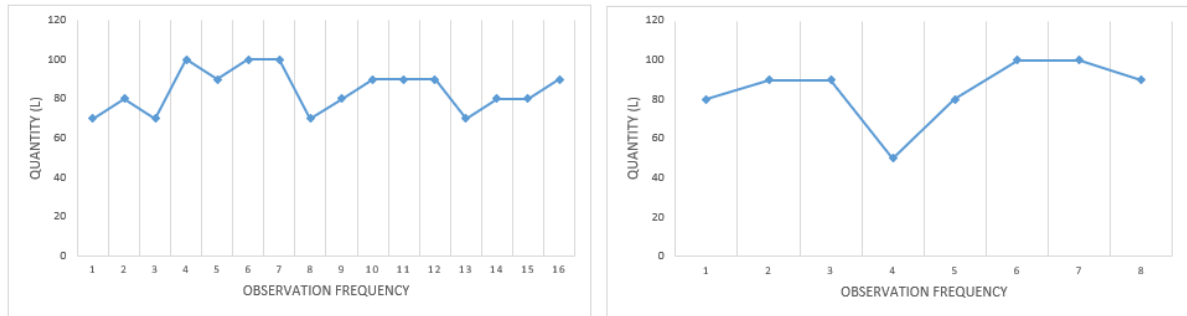


Figure 18 – Recorded quantities of solvent and water per wash, respectively

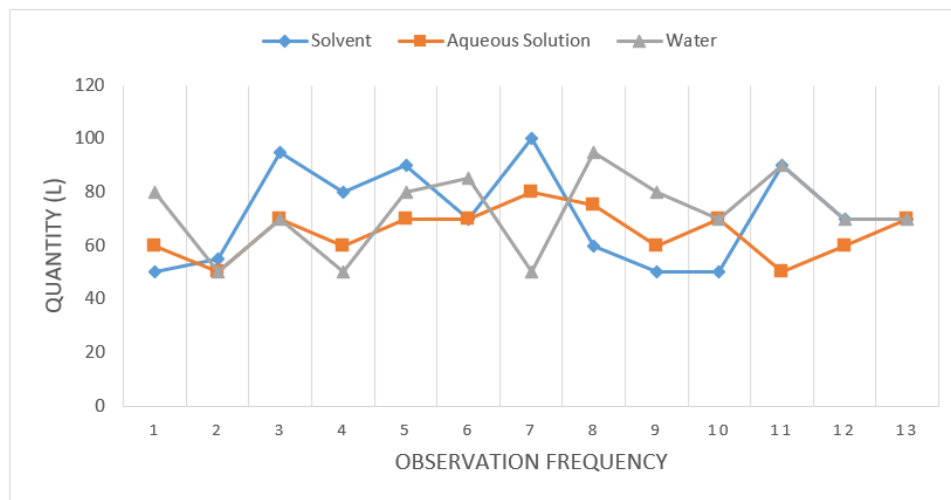


Figure 19 – Recorded quantities of each cleaning agent per wash

Based on the analysis, it can be concluded that, on average, approximately 85 litres of solvent or water are used in bead mill washings, where there is no change in the nature of the product. In contrast, when a change in product nature occurs, the average quantities used are 72 litres of solvent, 72 litres of water, and 65 litres of aqueous solution.

These results reinforced what had previously been written regarding a lack of standardisation and excessive consumption of cleaning agents. Combined with the absence of effective measurement tools and the use of an outdated, unclear procedure, this variability resulted in a process that was difficult to control and highly dependent on individual judgement.

Given the issues identified, there is a clear opportunity for improvement. These challenges will be addressed in the following chapter, where a set of specific measures are proposed and implemented with the aim of standardising the process, reducing waste generation, and improving operational control.

3.2.4 Fixed Tanks

Once a production batch has been completed, the fixed tanks used in the process must be properly washed before they can be used again. This step is crucial for preventing product contamination, ensuring consistent quality, and complying with safety and hygiene standards.

These fixed tanks are washed using an automatic internal cleaning system, specifically designed to clean the interior of large-volume containers. The equipment operates in a closed-circuit system, using a rotating washing head that sprays the cleaning agent onto the internal surfaces of the tank. There are two machines: one dedicated exclusively to water (LA-18) and the other to solvent (LA-19), shown in Figure 20.



Figure 20 – Fixed tanks washing machines

Each machine can be connected to any of the four available Dock Stations on the platform. All stations are equipped with the necessary infrastructure to support the washing process, including one input for connecting the machine to the power supply and another for connecting the network communication system. Each station also has four dedicated pipes supplying nitrogen, compressed air, solvent and water, as can be seen in Figure 21.



Figure 21 – Connection to Dock Station

At the start of each wash cycle, the operator selects one of three available modes: soft, medium or hard. The only difference between these modes is the washing duration, which directly affects the amount of cleaning agent consumed given the pump's fixed flow rate. Table 1

summarises the quantity of water or solvent consumed by each washing mode, based on the predefined durations and flow rates of the machines.

Table 1 – Washing modes consumption per machine

Machine	Mode	Washing Duration (min)	Flow Rate (L/min)	Consumption (L)
Water	Soft	2	30	60
	Medium	4		120
	Hard	6		180
Solvent	Soft	2	40	80
	Medium	4		160
	Hard	6		240

Solvent-based washes incorporate an additional step that involves introducing nitrogen into the tank before washing it. By contrast, water-based washes do not require nitrogen injection. The amount of nitrogen injected corresponds to the total internal volume of each tank, filling it completely, ensuring adequate pressure and safety for the operation. As shown in Table 2, the right-hand column represents the total volume of each tank, which is the volume occupied by nitrogen in each washing. The left-hand column shows the working volume, corresponding to the maximum amount of product that can be produced in a single batch. It is worth noting that, in the case of the DPHSD 06/07/08 and DP-21 dispersers, the total volume of the tanks is different from their intermediate tanks (IBT 05/06/07 and IBT 08/09, respectively), even though they can only produce the same amount.

Table 2 – Working and Total Volumes of Fixed Tanks

Tank	Working Volume	Total Volume
IBT 05/06/07	2800 L	3425 L
DPHSD 06/07/08	2800 L	3900 L
BT 11 to BT 22	4000 L	4745 L
IBT 08/09	8000 L	9731 L
DP-21	8000 L	9274 L
BT 23/24	14000 L	14425 L

Although it is possible to choose one of three washing modes, it was observed that operators mostly selected the hard mode by default, regardless of the condition of the tank or the type of product involved. This behaviour was not based on a formal assessment of cleaning needs but rather on assumptions and a lack of validation. In most cases, operators had never tested the effectiveness of the other modes and assumed that only the hard mode would ensure adequate cleaning.

Consequently, the washing mode was selected based on personal habits or beliefs rather than objective assessments. Furthermore, there were no standards or guidelines to determine which mode to use depending on the tank's previous contents, residue levels, or future use. This resulted in the systematic overuse of water or solvent, thereby increasing the environmental impact and operating costs.

To support this analysis, data was collected and analysed from all washing operations carried out in 2024 and during the first trimester of 2025. The results, presented in Figure 22, show how operators selected different washing modes for water-based and solvent-based washing. In both cases, it is evident that the hard mode was frequently selected, regardless of the tank's condition or the cleaning requirements.

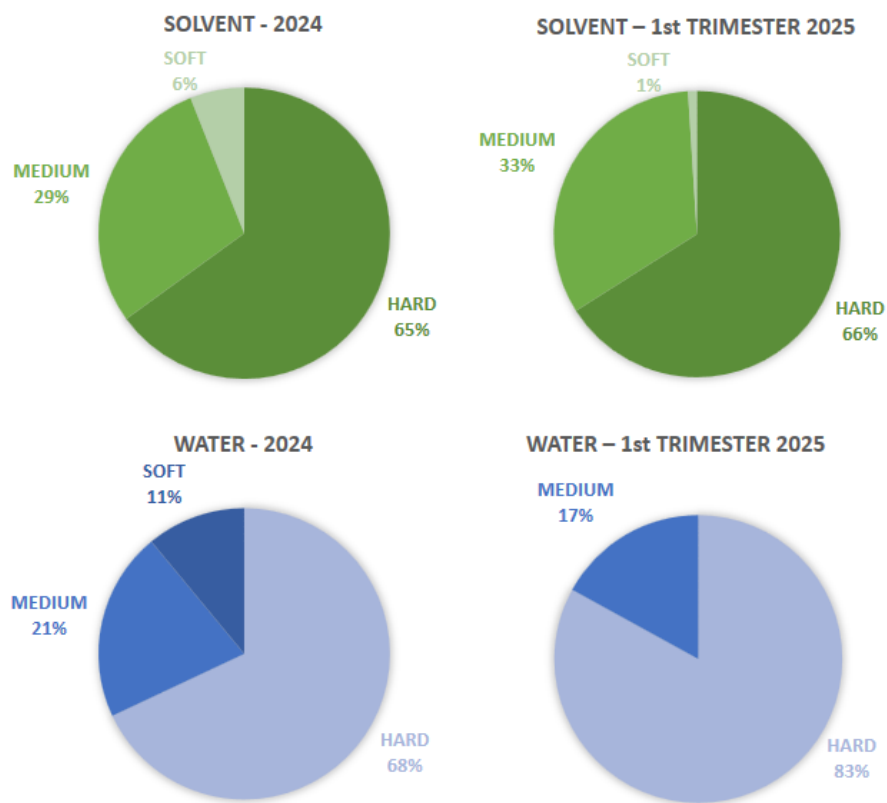


Figure 22 – Distribution of the washing mode used

This analysis confirmed the absence of standardised criteria for selecting the washing mode, revealing a strong tendency towards excessive use of the hard mode regardless of the actual cleaning requirements. These results highlight the need to standardise washing mode selection based on objective factors, such as the type of product to be washed and the size of the tank. It is essential to define clear guidelines and ensure that operators are properly informed and involved in the process in order to promote more sustainable practices, reduce waste generation, and improve overall efficiency.

4 Improvement Implementation

Based on the opportunities identified in Chapter 3, this chapter presents the set of improvement measures developed and implemented during the project. These improvements were implemented using methodologies such as 5S, Standard Work and SMED. The focus was on eliminating waste, improving standardisation, and increasing the efficiency of resources in the washing operations of the paint production unit.

4.1 Implementation of the 5S Methodology

In order to address the issues identified in subchapter 3.2.1, the 5S methodology was implemented as a foundation for structural improvement and consisted of:

- Assessment of needs and definition of objectives for the targeted areas, along with an inventory of existing materials and tools;
- Reorganisation of the workspace based on the conclusions obtained from the assessment phase;
- Cleaning of the areas;
- Standardisation of procedures along with an emphasis on the fifth step of the methodology, promoting long-term discipline and daily maintenance.

This intervention was executed with the active involvement of the operators, who provided insights about the proper use of tools and materials, along with recommendations for practical improvements. The collaboration of operators helped in the change process and increased the sustainability of the implemented changes.

Mobile Tank Storage Area

The implementation of the 5S methodology in the mobile tank storage area began with an assessment of the tanks normally placed in it. It was confirmed that only tanks ready for filling and awaiting approval should be stored in this area. It was also necessary to determine the normal operating capacity of the area.

Based on this information, the area was rearranged to ensure the required quantity could be accommodated in an orderly and accessible manner. The area was cleaned, and the layout was reorganised simultaneously, allowing immediate visual improvements. Ten dedicated positions were marked out on the floor as part of this intervention, creating defined locations for each tank, as can be seen in Figure 23.



Figure 23 – Mobile tank storage area after 5S implementation

This visual management tool avoided obstructions, ensured better identification of the tanks, and simplified the operators' daily operations. The clearly allocated space also facilitated compliance checks and supported the introduction of standardised working practices in the area.

The next phase involved establishing clear operational rules and ensuring that the operators consistently applied them. Operators were instructed to always place the tanks within the designated floor markings, ensuring that the product identification label and outlet valve faced outwards. This positioning enables the quick identification of tank contents and facilitates the early detection of potential leaks, thereby improving efficiency and safety.

The discipline aspect of the 5S approach relies on operators committing to these standards every day and maintaining a clean and organised area at all times.

Dispersion Area

The application of the 5S approach began with the identification and sorting of all items present in the area. Unnecessary or unused materials were then removed, and the remaining items were rearranged. Each item was given a labelled storage location, and visual indicators were placed on the floor and walls to help with identification and returning items after use.

A wall bracket was installed for storing the various cleaning tools, each of which was labelled on the wall to ensure that everything had a designated position. This improved accessibility and ensured that each item could be returned to its proper place after use, thus reinforcing the principles of visual management.

Following the improvements in material storage, wall brackets were also installed to hold the disperser protective covers and the cardboard sheets used to protect the floor during operations. These items had previously been left on the floor in a disorganised manner, causing visual clutter and limited accessibility. Now, the protective covers are stored vertically and safely, while the cardboard is neatly arranged on a dedicated shelf, improving both order and safety in the area.

In addition, a dedicated space was created for the mobile tanks used for cleaning the dispersers. Two designated areas were created on the floor to ensure these tanks were always stored in the same place, reducing disorganisation and making the workflow more predictable.

These implementations can be seen in Figure 24.



Figure 24 – Dispersion area after 5S implementation

To further streamline the preparation of new batches, the supply area, where the mobile tanks and raw materials are stored prior to being used for the dispersion process, was also reorganised. Six individual spaces were marked out on the floor, each designed to hold a mobile tank and its corresponding raw materials, all aligned in the same direction, as shown in Figure 25. This made handling the materials easier and ensured that everything needed for the next production run was grouped together and ready.



Figure 25 – Supply area after 5S implementation

In accordance with the fourth and fifth steps of the 5S methodology, a daily cleaning and verification checklist was created. This checklist (CLK186: Checklist de Limpeza e Preparação – Fabrico PV), presented in Appendix F, is used to assess the condition of the dispersion area on a daily basis, ensuring that the defined standards are consistently followed and that the space remains clean, organised, and functional over time. By incorporating this simple control tool into the routine, it becomes possible to detect deviations early, promote operator responsibility and reinforce the discipline needed to sustain the improvements achieved.

Grinding Support Trolley

Additionally, and in response to the ergonomic issue identified in Subchapter 3.2.1 regarding the support trolley used during the bead mills washing process, brakes were installed on the

trolley's wheels. This has significantly improved operator safety by reducing the risk of injury from uncontrolled movement during container handling.

4.2 SMED Analysis

As mentioned in subchapter 3.2.2, the time between one dispersion ending and the next beginning was identified as an area of significant opportunity for improvement. This interval, usually referred to as the cleaning and preparation setup, involves activities such as cleaning the dispersers, preparing the workspace and preparing the raw materials.

Therefore, a SMED analysis was conducted with the objective of reducing the setup time and increasing equipment availability. The methodology followed a structured approach composed of the following steps:

- Observation and identification of all tasks involved, using the Sequence Chart on Appendix D;
- Identification of internal and external tasks, converting the internal ones into external ones where possible;
- Study of the ideal method and task sequence;
- Revision and update of the standard related to this setup with the new optimal sequence;
- Testing of the updated standard and making of any necessary adjustments.

The process began by observing and analysing various preparation operations with the aim of identifying all the tasks involved and measuring the time needed to complete each. This approach made it possible to visualise the actual sequence in use, understand the duration of each stage and highlight inefficiencies.

Once this information had been gathered and an initial sequence of tasks outlined, a SMED workshop was held, as illustrated in Appendix G. The aim of the workshop was to validate the observed sequence and, through collaboration with the operators and the continuous improvement team, define the most efficient and practical order of execution. By incorporating feedback from the operators who carry out these activities on a daily basis, it was possible to identify opportunities to reorganise tasks, improve workflows, and simplify execution, all while maintaining safety standards and guaranteeing product quality.

All setup tasks were analysed and classified as internal or external. Those that were successfully converted to external are now assigned to a second operator and are therefore no longer considered part of the setup time itself.

Particular attention was given to tasks involving the use of a forklift, such as transporting mobile tanks, stacking pallets, and moving dirty materials to the washing area. These tasks were all designated as external and assigned to a second operator. This allows them to be performed in parallel with internal tasks, which are carried out by the main operator directly on the equipment. This division enables more efficient use of resources, minimises downtime, and improves the overall efficiency of the changeover process.

Additional opportunities for improvement were identified during the analysis to facilitate certain internal tasks and reduce their duration. As shown in Appendix G, green post-its represent actions that had been implemented prior to the workshop, and pink post-its correspond to improvements conceived during the workshop.

One of the improvements implemented prior to the workshop involved relocating the waste collection bins and the support trolley used in the dispersion area. Placing these items closer to the work area meant that Operator 1 could minimise movements during assembly, improving ergonomics and reducing the distances to be covered.

Another important measure was the introduction of an extra grid. This grid is placed on the dispenser lid in the area where the raw materials are introduced; without it, the equipment does not work. Previously, Operator 1 had to wash the grid during setup, which increased setup time and interrupted workflow. With an additional grid in place, a clean grid is always ready for use. As soon as the dirty grid is removed, Operator 2 takes it to the washing area and returns with a clean one, ensuring that a clean grid is always available. This adjustment eliminated a recurring bottleneck in the process and further strengthened the role of the second operator.

Among the improvements conceived during the SMED workshop, two particularly relevant issues were identified. Firstly, the positioning of the washing tank on the disperser proved to be unnecessarily time-consuming. Due to its smaller size compared to production tanks, operators often wasted time trying to centre it correctly, as there were no reference points or guides to assist with alignment. To solve this, a simple and effective solution was implemented: before placing the tank, the operator adjusts the disperser's side stoppers to the maximum. This ensures that the tank is correctly aligned when it touches both ends, avoiding repositioning and reducing the setup time.

A second problem observed was the occasional lack of necessary consumables at the time of the setup, forcing the operator to interrupt the process to retrieve the missing items. To resolve this issue, a checklist was created, as described in subchapter 4.1. With this checklist, the operator at the beginning of the shift ensures that all necessary materials for the day are available, so it will not be necessary to interrupt the process. This measure helped to simplify the process and contributed to better planning by operators and reduced wasted movements.

After defining the new sequence of tasks and implementing the relevant improvements, the setup was tested in real conditions. Based on the results obtained, a target setup time of 21 minutes was set. This represents a reduction of 13 minutes compared to the average setup time identified during the diagnostic phase (as described in Subchapter 3.2.2). Following this validation, the internal standard associated with the dispersion setup (NT 68/24: Utilização e Limpeza dos Dispersores) was formally revised and updated to include an improved

sequence, shown in Appendix H. The updated procedure ensures greater efficiency, consistency and alignment with the continuous improvement principles promoted by the SMED methodology.

To quantify the broader impact of the implemented improvements, an estimation of the annual time savings was performed. On average, 115 setup operations are carried out each month, which corresponds to approximately 1380 setups per year. Figure 26 compares the total annual time required for these operations under the previous procedure and after the implementation of the new, improved standard.

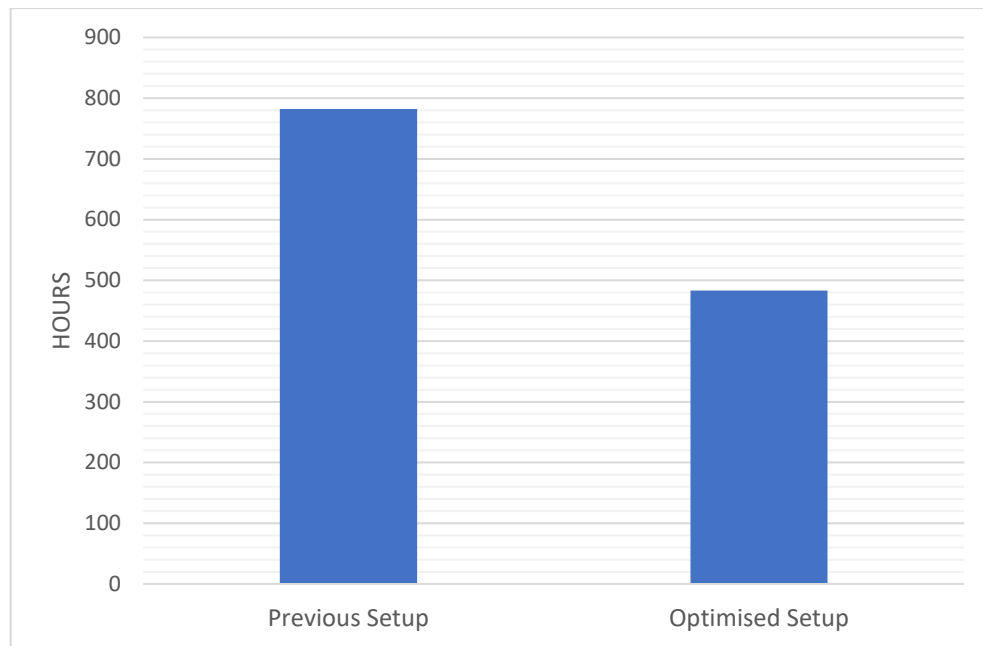


Figure 26 – Total estimated annual setup time

As illustrated, the improved procedure significantly reduces total setup time throughout the year. While the previous method resulted in a cumulative setup time of approximately 46920 minutes, the improved approach reduces this to 28980 minutes. This equates to an annual gain of almost 300 hours, demonstrating the substantial increase in sector productivity and equipment availability that can be achieved through SMED-based improvements.

4.3 Waste Reduction and Standardisation in Bead Mill Washings

One of the first measures taken to improve the washing process for the bead mills was to update the existing document, presented in Appendix E, allowing for the study and analysis of the quantities used in mill washing to begin. Although the original document allowed for basic recording of the process, it lacked clarity and key information. This made it difficult to determine the type of washing performed or to analyse the data effectively.

In addition, the document did not allow for the recording of the next product to be processed, which made it difficult to understand and distinguish the cleaning agents and quantities being used. To solve this problem, an additional column was added to register the next product to be ground, making the document more comprehensive and facilitating a clearer understanding of the logic behind each wash.

This change made it easier to distinguish between washes and allowed for more accurate recording of cleaning agent quantities. As a result, the data collected became much clearer and more useful for analysis, providing a basis for defining more appropriate washing parameters tailored to the actual needs of the process.

Following this, consideration was given to resolving the issue of a lack of control over the quantities of cleaning agents used. As previously mentioned, without weighing the quantities placed in the containers, it was impossible to accurately determine the amount used.

To address this issue, litre scales were installed inside the containers, as illustrated in Figure 27, enabling operators to visually monitor the volume used in each wash. This simple measure enabled more accurate and consistent quantities to be used, reducing reliance on personal

judgement and helping to align daily practice with the values defined during the subsequent improvement phase.

As a result, operators were able to carry out the washing process with greater precision, contributing to better standardisation and significantly reducing unnecessary waste.



Figure 27 – Litre scales implemented

Given the positive impact of this measure, the same approach was adopted in another area of the C1. Scales were added to the containers used to wash the filling machines, allowing operators to monitor the volumes of cleaning products used more accurately. This measure helped to promote consistency between different operations and reinforced the importance of visual control in reducing waste and improving process reliability.

After ensuring adequate data collection and installing visual measurement tools, the next step was to define standard reference values for the quantities of cleaning agents required in different cases. The main objective was to standardise the process by providing operators with clear, predefined limits for each type of wash in order to reduce variability and avoid unnecessary waste.

At the same time, the main objective of the initiative was to reduce waste generation. To achieve this, a series of controlled tests were conducted under real conditions to determine the maximum amount needed to perform an effective wash. Throughout this process, regular discussions were held with operators in order to gather their opinions and better understand how they determine whether a wash is considered effective or not. Their input was fundamental to adjust the values realistically and ensuring that the solution would be accepted and applicable in daily practice.

Following this, specific reference values were established depending on the relationship between the previous and the next product to be processed.

For washing between products of the same nature, the new reference value was set at 70 litres, representing a reduction of 15 litres per wash.

In cases where the nature of the product changes, a value of 50 litres was set for each of the three cleaning phases: solvent, aqueous solution and water. Compared to the average quantities referenced in chapter 3.2.3, this measure resulted in a reduction of 22 litres for the solvent and water phases and 15 litres for the aqueous solution.

As an additional opportunity for improvement, a third type of wash was considered for cases where the next product is of the same nature, from the same family and in the same colour range. In these cases, a lower reference value of 50 litres was introduced, representing a reduction of 35 litres per wash. This adjustment recognises that such transitions require less intense cleaning, allowing for a greater reduction in consumption without compromising the integrity of the process.

In cases where the next product is exactly the same as the previous one, it was determined that no washing is necessary, allowing the mill to proceed directly with the next batch.

In collaboration with the operators, an additional opportunity to reduce the use of cleaning agents was identified and implemented. For certain products, the finishing phase includes a predefined step called mill washing, as shown in Figure 28. This involves adding part of the remaining raw materials through the bead mill instead of directly into the tank.

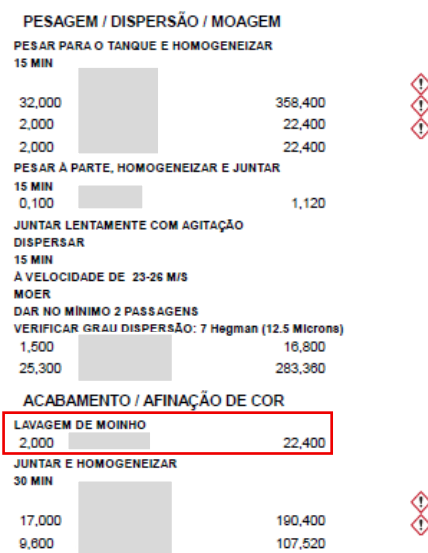


Figure 28 – Example of mill washing step

Although this addition helps to remove product residues from inside the mill, in most cases it is not sufficient on its own, and a full wash is still required afterwards. To improve this practice, it was agreed that whenever the quantity added in this step is equal to or greater than the defined reference value for washing, a subsequent wash can be safely omitted.

In cases involving a change in product nature, this same logic allows the process to skip the first cleaning step (corresponding to the previous product), proceeding only with the aqueous solution and the next product's agent.

By formalising this rule, the process became more efficient, allowing operators to take advantage of existing steps in the recipe to reduce the need for additional washing while maintaining product quality and processing reliability.

Following this, the existing standard (NT 20/24: Operação de Moagem Nave Central – Pequenos e Grandes Volumes) has been revised and updated to reflect the changes introduced. This can be seen in Appendix I.

A simulation study was carried out using actual production data from the first four months of 2025 to assess the potential impact of the improvements introduced. Table 3 summarises the total number of washes performed during this period, categorised by mill and wash type.

Table 3 – Number of washes performed per mill and wash type

Type	ML23	ML10	ML35	ML36	ML37	ML31	Total
Water - Water	2	9	0	0	0	0	11
Solvent - Solvent	20	33	20	21	19	7	120
Change of Nature	14	18	4	0	6	4	46
Same family and colour range	0	0	2	0	5	0	7

The total consumption of cleaning agents was calculated based on the number of washes recorded in the previous table and the average volumes previously used by operators, as described in subchapter 3.2.3. The obtained values are shown in Table 4.

Table 4 – Cleaning agent's consumption per wash type

Type	Solvent (L)	Water (L)	Aqueous Solution (L)
Water - Water	-	935	-
Solvent - Solvent	10200	-	-
Change of Nature	3312	3312	2990
Same family and colour range	595	-	-

These values were then compared to the estimated consumption that would have occurred if the newly standardised values had already been in place, taking into account the three types of washing defined during the project. Applying the newly defined standard values to the number and type of washes actually performed made it possible to calculate the quantities that would be saved during these four months, as shown in Table 5.

Table 5 – Estimated cleaning agent's consumption

Cleaning Agent	Analysed Consumption (L)	Estimated Consumption (L)	Reduction (L)	Savings
Solvent	14107	11050	3057	22%
Water	4247	3070	1177	28%
Aqueous Solution	2990	2300	690	23%

After analysing Table 5, it is possible to confirm that the application of the newly defined standardised values would have led to a significant reduction of 4924 litres over the four-month period examined. This includes a reduction of 3057 litres of solvent, 1177 litres of water and 690 litres of aqueous solution.

Figure 29 provides a projection of the estimated annual consumption of each cleaning agent, offering a clearer illustration of the overall impact of the improvement measures implemented. The graph compares projected consumption under current procedures with expected values if the new standard were applied consistently throughout the year.

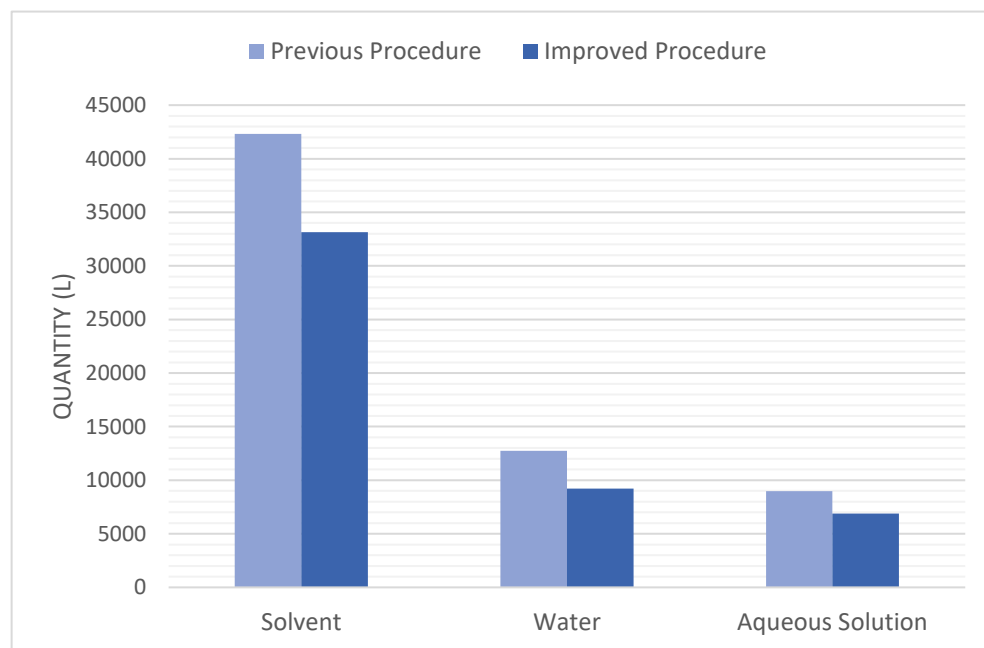


Figure 29 – Estimated annual cleaning agent's consumption in bead mills washing

After consolidating the results, the implementation of the improved washing parameters in the bead mills would lead to a total annual reduction of 14772 litres of cleaning agents. This improvement includes a saving of 9171 litres of solvent, 3531 litres of water, and 2070 litres of aqueous solution. These results highlight the widespread impact of the improvements across all cleaning agent types. The combined effect represents a 23% reduction in total annual consumption, confirming that even relatively simple standardisation actions can produce significant gains in resource efficiency when scaled to full-year operations.

4.4 Waste Reduction and Standardisation in Fixed Tanks Washings

As stated in Subchapter 3.2.4, the majority of washing operations in fixed tanks were performed using the hard mode, regardless of the actual need. This approach led to the overuse of water or solvent, depending on the product, and highlighted a lack of criteria in selecting the most appropriate washing mode.

In order to assess the potential for reducing the use of the hard mode, a series of tank washes were monitored on site. A photographic record was taken before and after each wash to evaluate the effectiveness of the different modes. Depending on the tank's condition, size and type of product, lower modes were progressively tested until a satisfactory result was achieved.

This practical approach allowed for a direct comparison of cleaning effectiveness across different modes, making it possible to identify situations in which the hard mode was unnecessary. The aim was to determine the most appropriate mode for each scenario, ensuring effective cleaning while avoiding excessive water or solvent usage.

In the five tanks associated with large-volume production (DP-21, IBT08, IBT09, BT23 and BT24), used exclusively for solvent-based products, it was standard practice among operators to perform two consecutive hard washes, as this was considered the only way to ensure proper cleaning. According to their experience, a single hard wash was insufficient to effectively remove all residues.

According to the analysis carried out across different washing scenarios, it was confirmed that a single hard wash was not sufficient to properly clean the tank. However, the results also showed that two hard washes were not necessary, as had been the standard practice. Instead, one of them could be replaced by a medium wash, maintaining cleaning effectiveness while allowing for a reduction in solvent consumption.

In addition, carrying out two separate washes meant that nitrogen had to be injected twice since the system automatically introduces nitrogen at the start of each wash cycle. As mentioned in subchapter 3.2.4, a hard wash takes 6 minutes, whereas a medium wash takes 4 minutes. Based on these parameters, the hard mode wash recipe in these five tanks was manually modified in the machine to increase its duration from 6 to 10 minutes.

This modification enabled the machine to achieve both medium and hard wash cleaning effects with a single, extended hard wash. Consequently, this adjustment reduced nitrogen consumption by 50% while maintaining cleaning effectiveness and reducing total washing time.

Table 6 quantifies the impact of this change by presenting the estimated reduction in solvent and nitrogen consumption for each washing cycle performed in these five tanks. This compares the previous procedure, which involved two full washes, with the newly improved process, which combines both cleaning phases into a single, extended hard wash. In addition, the table also includes the estimated savings per wash, reflecting the combined effect of reduced solvent and nitrogen usage.

Table 6 – Solvent and nitrogen consumption per wash

Tank		Previous Consumption (L)	New Consumption (L)	Reduction (L)	Savings
IBT 08/09	Solvent	480	400	80	49%
	Nitrogen	19462	9731	9731	
DP-21	Solvent	480	400	80	49%
	Nitrogen	18548	9274	9274	
BT 23/24	Solvent	480	400	80	49%
	Nitrogen	28850	14425	14425	

To assess the wider impact of this improvement, a simulation study covering all washing operations in these five tanks during the first three months of 2025 was carried out and is presented in Table 7. As with the bead mills, the aim was to compare actual consumption with what would have been recorded if the improved procedure had been applied from the start. This enabled a detailed estimate to be made of the total potential reduction of solvent and nitrogen and associated savings during that period.

Table 7 – Estimated consumption of solvent and nitrogen per washing cycle

	Tank	Frequency	Analysed Consumption (L)	Estimated Consumption (L)	Reduction (L)	Savings
Solvent	IBT 08/09	11	5280	4400	880	17%
	DP-21	7	3360	2800	560	
	BT 23/24	9	4320	3600	720	
Nitrogen	IBT 08/09	11	214082	107041	107041	50%
	DP-21	7	129836	64918	64918	
	BT 23/24	9	259650	129825	129825	

It is possible to confirm that implementing the new washing strategy would result in significant reductions during the first three months of 2025. Overall, solvent consumption would have

decreased by 2160 litres, and nitrogen consumption by 301784 litres across the five large-volume tanks.

These reductions would not only have had a significant environmental impact but also a clear financial one, given the considerable cost of both the cleaning agent and nitrogen. The total estimated savings for this period is 17% for solvent consumption and 50% for nitrogen consumption.

This result confirms the effectiveness of the implemented change and shows that adjusting the washing parameters without changing the equipment can deliver measurable improvements in operational efficiency and waste optimisation.

In addition to reducing solvent and nitrogen consumption, this implementation resulted in shorter washing times. By eliminating the need for two separate cycles, the process now takes less time to complete, meaning the machine is available sooner for the next tank. Consequently, the tank is ready for the next production batch earlier, thereby contributing to increase overall production efficiency, productivity and resource utilisation.

Each washing cycle is composed of four stages: nitrogen injection, washing, emptying, and ventilation. The ventilation time (two minutes) and emptying time (one minute) are constant across all tanks and washing modes. However, the nitrogen injection time varies depending on the tank's volume, the pressure conditions, and the flow rate. This time was calculated using an Excel worksheet that considers these parameters, presented in Appendix J.

The time saved in each washing operation is detailed in Table 8.

Table 8 – Washing operation time reduction per tank and per wash

Tank	Previous Time (min)	New Time (min)	Reduction (min)	Savings
IBT 08/09	48	28	20	42%
DP-21	46	27	19	41%
BT 23/24	62	35	27	44%

In the remaining fixed tanks, operators typically performed a single wash, using the hard mode by default. The main objective in this area was therefore to assess the necessity of such intensive washing and to determine the most suitable washing mode for each tank, with the aim of reducing the unnecessary use of the hard mode.

This evaluation focused exclusively on solvent-based products, since their behaviour during the washing process is more predictable. Due to the presence of vapours, solvent-based products tend to detach more easily from the tank walls, allowing other modes to be used instead of the hard one. On the other hand, water-based products dry much faster, which affects their adherence to the tank walls and results in unpredictable residues, making it impossible to define standardised washing configurations. Therefore, the existing procedures for aqueous products were maintained. However, operators were encouraged to assess the condition of the tank after each batch and, where possible, to experiment with lower washing modes where possible, helping to promote greater awareness and resource-conscious decision-making.

In addition, during the initial production phase, before the finishing phase is complete, the product is often pasty and less fluid. This makes it difficult to predict how easily it will come off the tank walls during washing. This is particularly true of DPHSD06 and DPHSD08, as well as their associated intermediate tanks (IBT05 and IBT07), due to the use of different types of products, which makes the variability of the products' behaviour greater. This variability has made it impossible to define a standardised washing procedure for these tanks.

On the other hand, the DPHSD07 disperser, which produces only colourless, solvent-based products, showed consistent enough washing behaviour to allow a defined washing mode to be implemented. Consequently, it was possible to analyse and implement an improved washing mode on this disperser and its intermediate tank (IBT06).

Based on observations and washing tests, it was determined that soft mode ensures adequate cleaning in both the DPHSD07 and IBT06. The consistency of the colourless, solvent-based products processed in these tanks allowed for the adoption of this lower-intensity washing mode without compromising efficiency.

To estimate the potential impact of this change, a simulation was carried out using data from all washes in these two tanks during the first three months of 2025. Table 9 shows how often each washing mode was used during this period and calculates the estimated reduction in solvent consumption and the corresponding monetary savings that would have resulted from using the soft mode in all cases.

Table 9 – Estimated solvent consumption in DPHSD07 and IBT06

Previous Mode	Frequency	Analysed Consumption (L)	New Mode	Frequency	Estimated Consumption (L)	Reduction (L)	Savings
Hard	26	6240	Soft	57	4560	6640	58%
Medium	31	4960					
Soft	4	320	-	-	320	0	

As can be observed, converting all washes would have resulted in a total reduction of 6640 litres of solvent over the first three months of 2025, which results in savings of 58%.

At the same time, efforts were made to standardise the washing procedures for the final tanks IBT11 to IBT22. At this stage of production, the product has already passed through the finishing phase, resulting in a more fluid formulation. This increased fluidity makes it easier to remove the residues from the tank walls, making it possible to use less intensive washing modes without compromising cleaning effectiveness.

It was therefore established that the soft mode should be used for colourless products, and the medium mode should be applied to all other solvent-based products.

A simulation was also carried out to estimate the potential reductions that could be achieved. For this analysis, records from the first three months of 2025 were reviewed to determine the frequency of each washing mode and classify products as colourless or non-colourless.

The analysis revealed that, in 57% of cases, the products were not colourless and would therefore require the medium mode under the new guidelines. The remaining 43% were

colourless and thus eligible for the soft mode. Based on this distribution, the simulation converted 57% of previously used hard washes to medium and 43% of both hard and medium washes to soft.

Table 10 shows the estimated reductions in solvent consumption by comparing the modes that were actually used with those that would have been applied under the new standard.

Table 10 – Estimated solvent consumption in final tanks

Previous Mode	Frequency	Analysed Consumption (L)	New Mode	Frequency	Estimated Consumption (L)	Reduction (L)	Savings
Hard	81	19440	Medium	46	7360	9280	43%
			Soft	35	2800		
Medium	25	4000	Medium	14	2240	880	
			Soft	11	880		

As can be observed, converting all washes would have resulted in a total reduction of 10160 litres of solvent over the first three months of 2025, which results in savings of 43%.

Following this, the existing standard (NT 39_24: Operação de Lavagem de Tanques Fixos) has been revised and updated to reflect the changes introduced. This can be seen in Appendix K.

To account for potential deviations in real production scenarios, an additional simulation was conducted, assuming a 20% failure rate with the new washing strategy. In this scenario, 20% of the washes were considered unsuccessful and therefore needed to be repeated using the same cycle. This simulation was applied to DPHSD07, IBT06 and the final tanks (IBT11 to IBT22).

Table 11 shows the results of the simulation for the DPHSD07 and IBT06 tanks. Three scenarios are compared: the current procedure, the ideal application of the new standard with a 100% success rate, and a conservative scenario in which 20% of washes are assumed to require repetition. In this simulation, the 20% rewash scenario corresponds to an additional 12 soft washes added to the improved plan. These extra cycles were deemed sufficient to account for potential failures in cleaning effectiveness, providing a more realistic projection of total consumption. The table compares the total consumption of solvent and nitrogen in each scenario, along with the overall cost savings achieved relative to the current procedure.

Table 11 – Estimated consumption of solvent and nitrogen in DPHSD07 and IBT06 with 20% failure rate

	Solvent Consumption (L)	Nitrogen Consumption (L)	Cost Savings
Analysed	11520	223413	-
Estimated	4880	223413	54%
Estimated + 20% failure	5840	267363	45%

Table 12 shows the results of the simulation carried out on the final tanks, IBT11 to IBT22. To evaluate the resilience of this new standard in less favourable conditions, two additional scenarios were simulated: one assumes that 20% of the washes would need to be repeated in soft mode and the other assumes that 20% would require repetition using medium mode.

In both cases, this corresponds to an additional 21 washes, added proportionally to the improved plan. The table compares the total consumption of solvent and nitrogen in each scenario, along with the overall savings achieved relative to the current procedure.

Table 12 - Estimated consumption of solvent and nitrogen in final tanks with 20% failure rate

	Solvent Consumption (L)	Nitrogen Consumption (L)	Cost Savings
Analysed	23440	502970	-
Estimated	13280	502970	41%
Estimated + 20% Medium	16640	602615	33%
Estimated + 20% Soft	14960	602615	26%

The results of both simulations demonstrate that the proposed washing strategy remains effective even under non-ideal conditions. Assuming a failure rate of 20% with repeated washing, the total consumption of solvent and nitrogen increases slightly compared to the ideal scenario in both cases. Nevertheless, significant monetary savings are still achieved compared to the current standard.

Notably, solvent consumption remains significantly lower in both cases, even when these additional washing cycles are taken into account. These results confirm that standardisation for more efficient washing methods continues to offer clear environmental and economic advantages, even when some washing requires repetition.

To better illustrate the global impact of the implemented improvement measures, Figure 30 presents a projection of the estimated annual solvent consumption across all fixed tanks. The chart compares the projected consumption under the current procedures with the values expected if the new standard were applied consistently throughout the year. As shown, all

groups of tanks would experience significant reductions in solvent consumption. This visual summary reinforces the effectiveness and scalability of the proposed improvements.

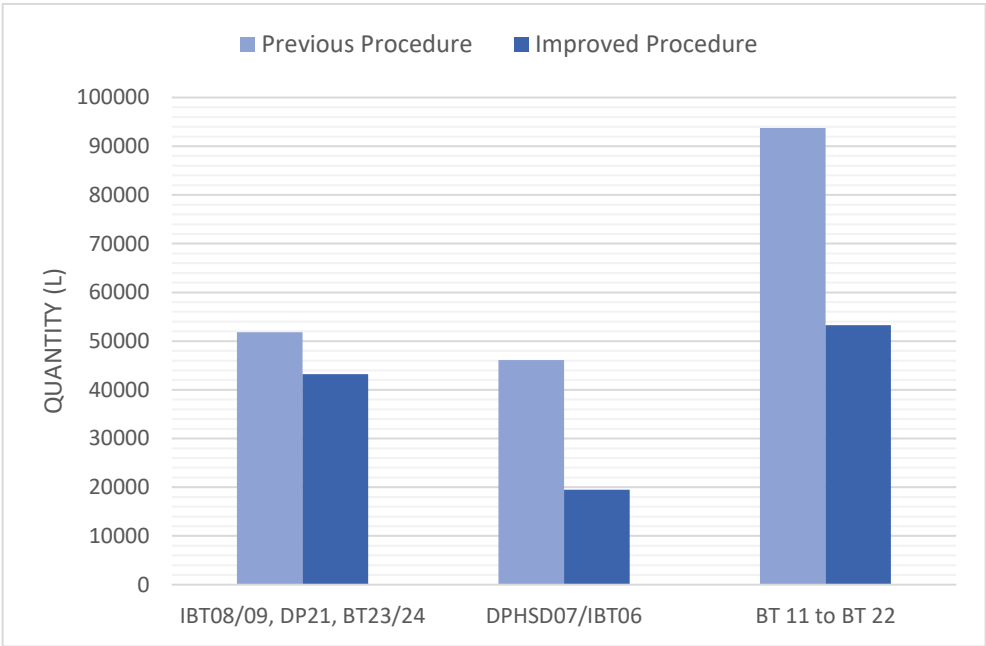


Figure 30 – Estimated annual solvent consumption in fixed tanks washing

When consolidating the results, total solvent consumption under the previous procedure would amount to 243840 litres per year, also considering the consumption of the four tanks where no improvements could be made. With the improved procedure the consumption would be 168000 litres, which translates to a total annual savings of 31%. This calculation assumes an equivalent number of washing cycles in all quarters of the year, based on the activity recorded during the first trimester.

5 Conclusions

As outlined in the initial phase of this project, the application of Kaizen-based methodologies plays a fundamental role in improving operational performance and promoting sustainability in modern industry. In a production environment where resource efficiency and environmental impact have become strategic priorities, continuous improvement emerges as a key enabler.

Within this context, the present project was developed with a clear and pragmatic objective: to identify and understand the root causes behind the increase in waste generation and to implement Kaizen-driven improvements capable of reducing waste and stabilising operations. Relying on tools such as Standard Work, 5S, and SMED, the project aimed to standardise procedures, eliminate unnecessary variability, and foster conscious, sustainable behaviour on the shop floor.

A key aspect of the project's success was the active involvement of the operators throughout all stages of the project, from problem diagnosis and testing to standard validation. This inclusive approach promoted ownership and accountability, leading to a behavioural shift towards greater resource consciousness and process discipline.

During the diagnostic phase, two areas emerged as the primary sources of waste generation in the Central Hall: the washing of bead mills and fixed tanks. Although these processes were routine, they accounted for a disproportionate amount of water and solvent consumption, making them the primary focus of the project. Meanwhile, two other areas were identified, where significant organisational inefficiencies were affecting performance. A setup process in the dispersion area was found to be unnecessarily long and variable, resulting in the waste of time and resources.

In the bead mill washings, the definition of updated consumption limits has enabled significant reductions in consumption per type of wash. It has been determined that the amount of solvent, or water, required for washing between products of the same nature has been reduced by 15 litres per operation. In washes involving a change of nature, consumption was reduced by 22 litres in the solvent and water phases and by 15 litres in the intermediate phase with aqueous solution. For washings between products of the same family and colour range, it was possible to reduce consumption by 35 litres per wash. These reductions were subjected to technical validation and incorporated into the updated standard, thereby ensuring future consistency in operations.

The implementation of these measures resulted in a significant improvement in terms of sustainability and efficiency. Based on actual data from the first four months of 2025, a simulation was carried out that projected an annual reduction of approximately 14772 litres of cleaning agents, distributed between 9171 litres of solvent, 3531 litres of water, and 2070 litres of aqueous solution. The result represents a total savings of 23% in the consumption of these resources in the mill washing operation. In addition to the environmental and economic benefits, these improvements have helped reinforce the culture of standardisation, promote operator involvement, and reduce variability in the process, in line with the Kaizen principles of continuous improvement and visual management.

Regarding the washing of fixed tanks, a set of targeted improvements were implemented across multiple tank groups, leading to substantial solvent savings. These changes projected a total annual reduction of 75840 litres of solvent, corresponding to a total savings of 31% in the overall solvent consumption. In economic terms, these reductions translate into a considerable decrease in the operating costs associated with washing operations. Operationally, they contribute to shorter cleaning cycles, greater equipment availability and more consistent work

routines. These results demonstrate how structured observation, operator collaboration, and methodical testing can be used to transform a process that was previously driven by habit and perception into a standardised, efficient, and sustainable operation.

The third area addressed was the disperser cleaning and preparation setup. Initial observations revealed considerable variability in execution time, with setups often exceeding 30 minutes. To tackle this issue, a structured SMED analysis was carried out. A collaborative workshop with the operators and the continuous improvement team was conducted to identify inefficiencies and define an optimal sequence.

Following this, the revised standard reduced the average setup time from 34 to 21 minutes. With approximately 1380 setups performed annually, this represents a gain of nearly 300 hours of equipment availability per year. Beyond the numerical improvement, the intervention brought consistency and predictability to the process, reducing operator stress and facilitating smoother transitions between batches. This case highlights the effectiveness of SMED, not only in reducing setup times but also in cultivating a culture of anticipation, discipline, and continuous improvement.

The 5S methodology was applied in both areas through a structured implementation process: sorting unnecessary items, placing all tools and materials in order, deep cleaning, standardising procedures, and sustaining the improvements through daily routines. These changes not only improved accessibility and efficiency but also promoted a safer and more professional working environment. As a result, both areas underwent a transformation, not only in layout but also in behaviour and accountability. From a Kaizen perspective, this intervention demonstrated how even simple, low-cost changes, when planned with discipline and executed in collaboration with the team, can have a meaningful and lasting impact on performance, quality, and workplace satisfaction.

The improvements implemented throughout the project not only improved operational efficiency but also aligned with the principles of Environmental, Social, and Governance (ESG). From an environmental perspective, the reductions in water, solvent, and nitrogen usage directly translate into a lower ecological footprint and more responsible resource consumption. The introduction of visual controls, predefined limits, and standard procedures has reinforced governance, ensuring greater process transparency, traceability, and compliance with internal standards. Moreover, the active involvement of frontline workers in every improvement initiative, through collaborative workshops, standard revisions, and daily checklists, reflects a strong social commitment to employee participation, safety, and engagement. In this sense, the Kaizen philosophy acted as a practical enabler of ESG values, demonstrating how structured, continuous improvement can be a driver of industrial sustainability.

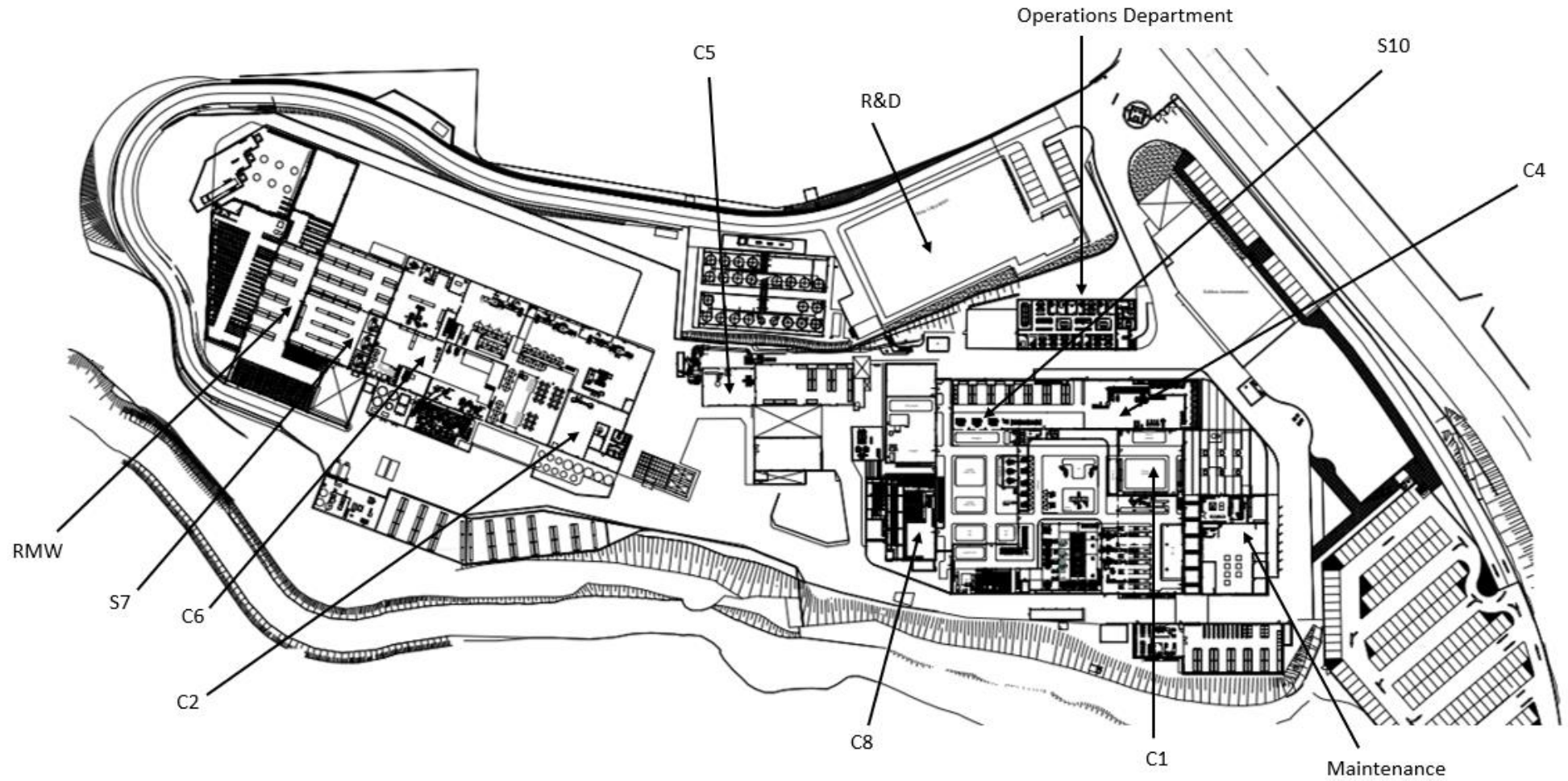
Looking back at the project as a whole, it can be concluded that the main objectives have been successfully achieved. Through a structured, data-driven approach grounded in Kaizen methodologies, it was possible to stabilise operations, eliminate waste sources, and promote a more sustainable and standardised production system. Resource consumption in both washing operations was significantly reduced, surpassing the initial 10% waste reduction target. The implementation of SMED in the dispersion area led to measurable gains in equipment availability, while the application of 5S brought lasting improvements to workplace organisation and operator discipline. Most importantly, these results were not the product of isolated interventions but rather of a continuous improvement mindset, embedded into daily routines and supported by those who carry out the work. By combining operational excellence with environmental responsibility and social involvement, the project delivered tangible results and laid the foundation for a more resilient, efficient, and sustainable future in the production unit.

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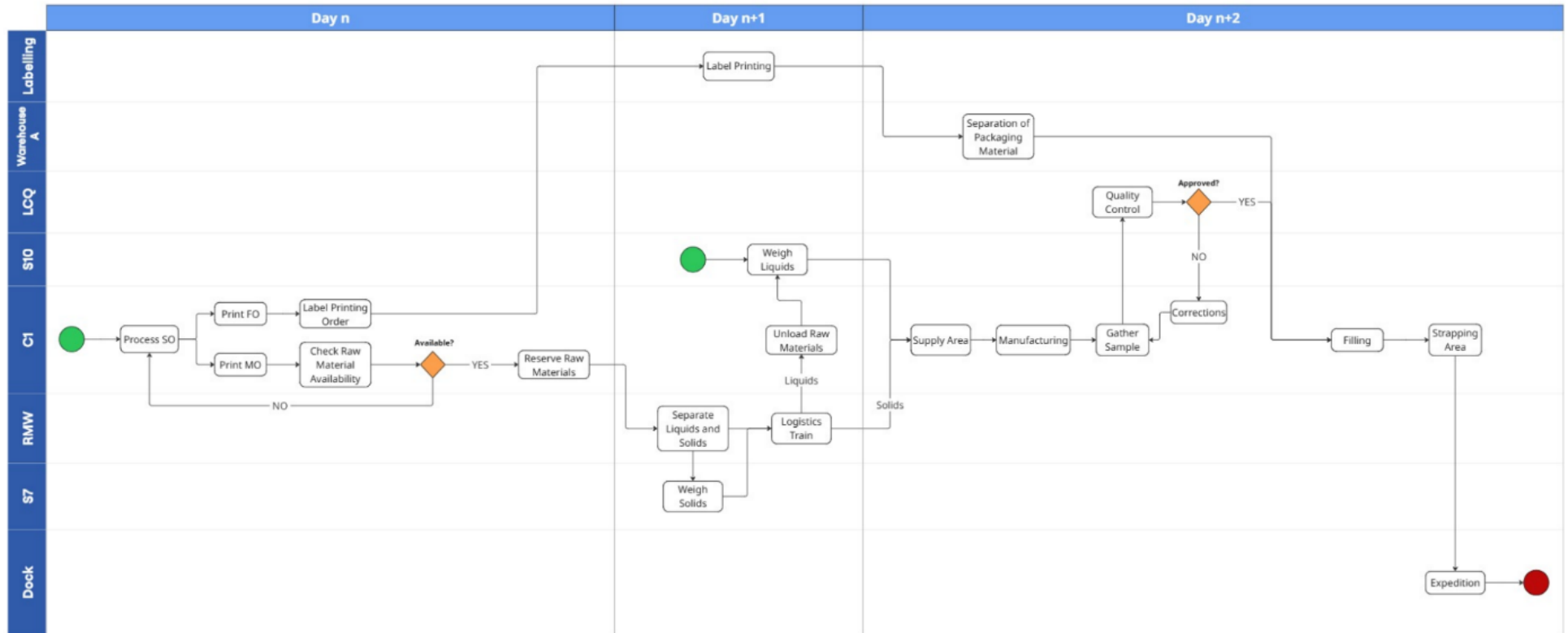
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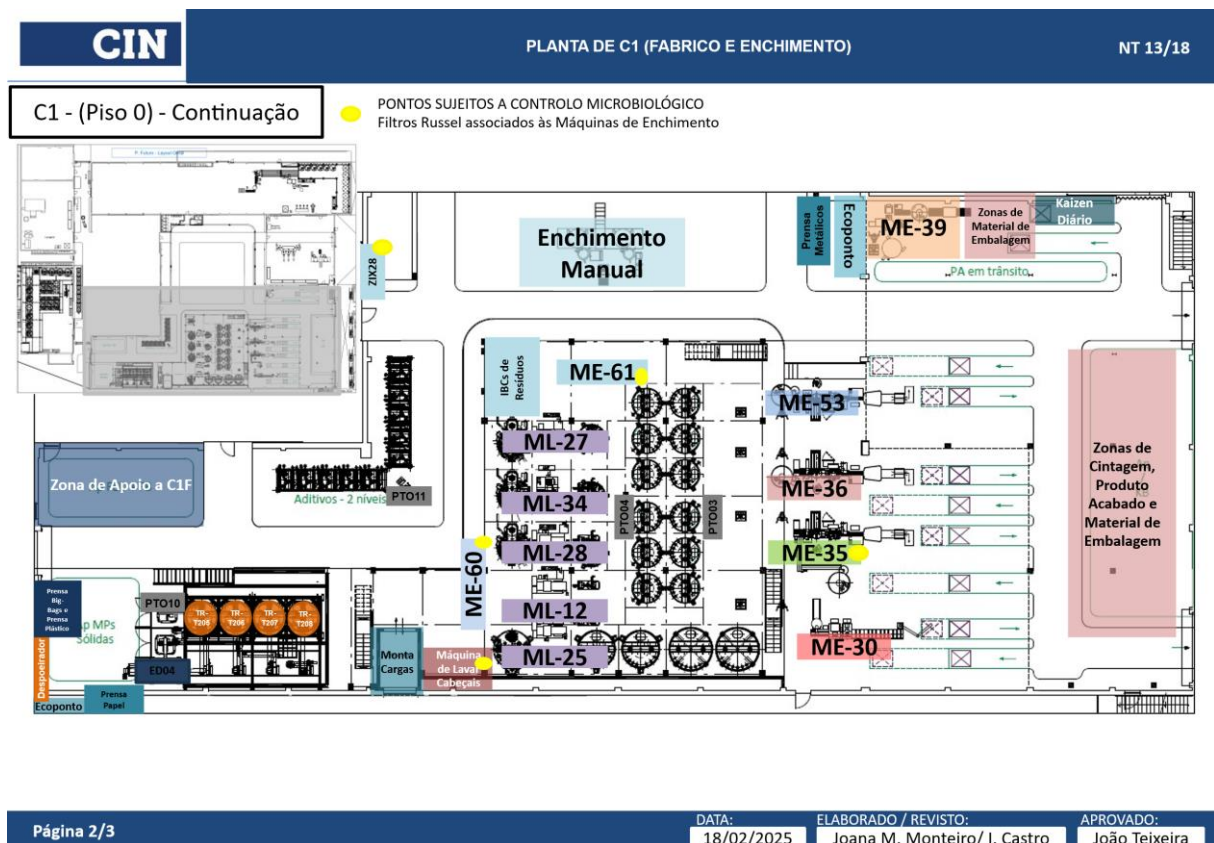
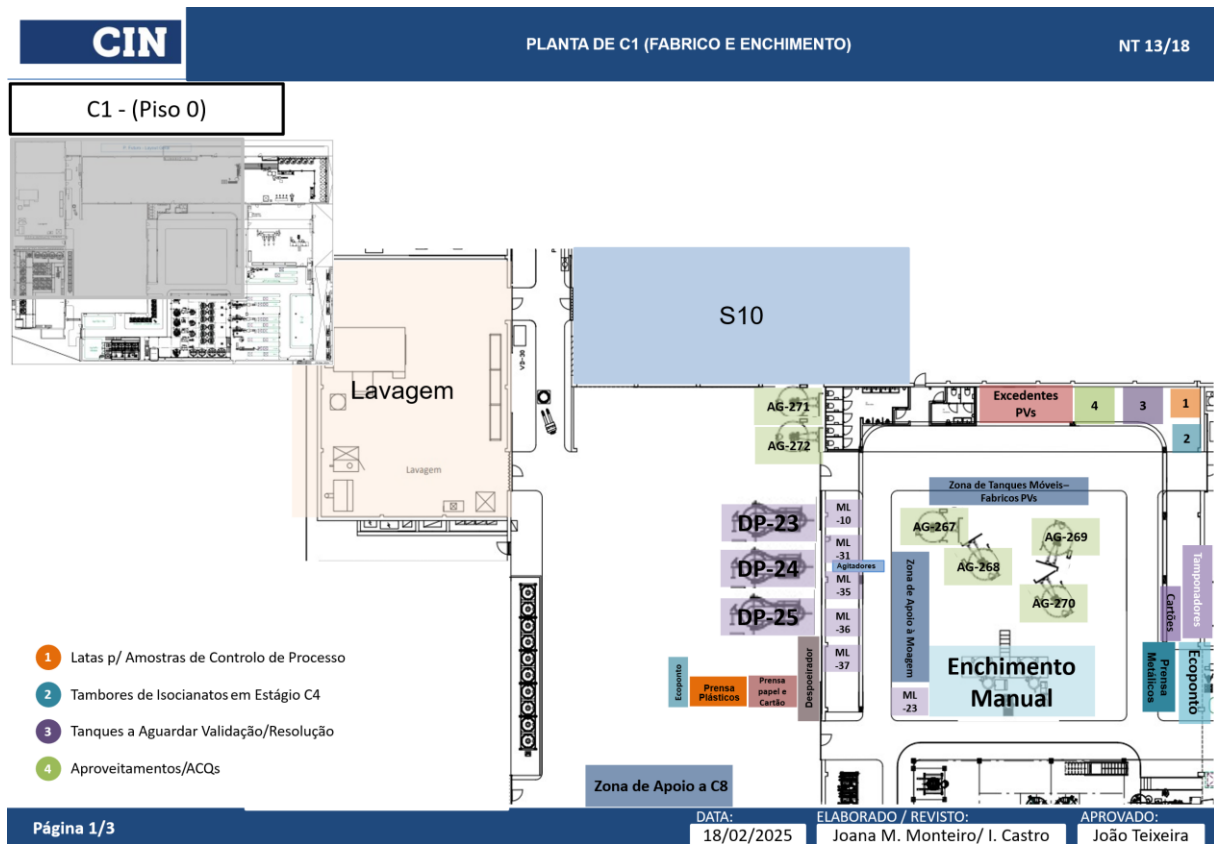
Appendix A: Plant Layout of CIN Headquarters

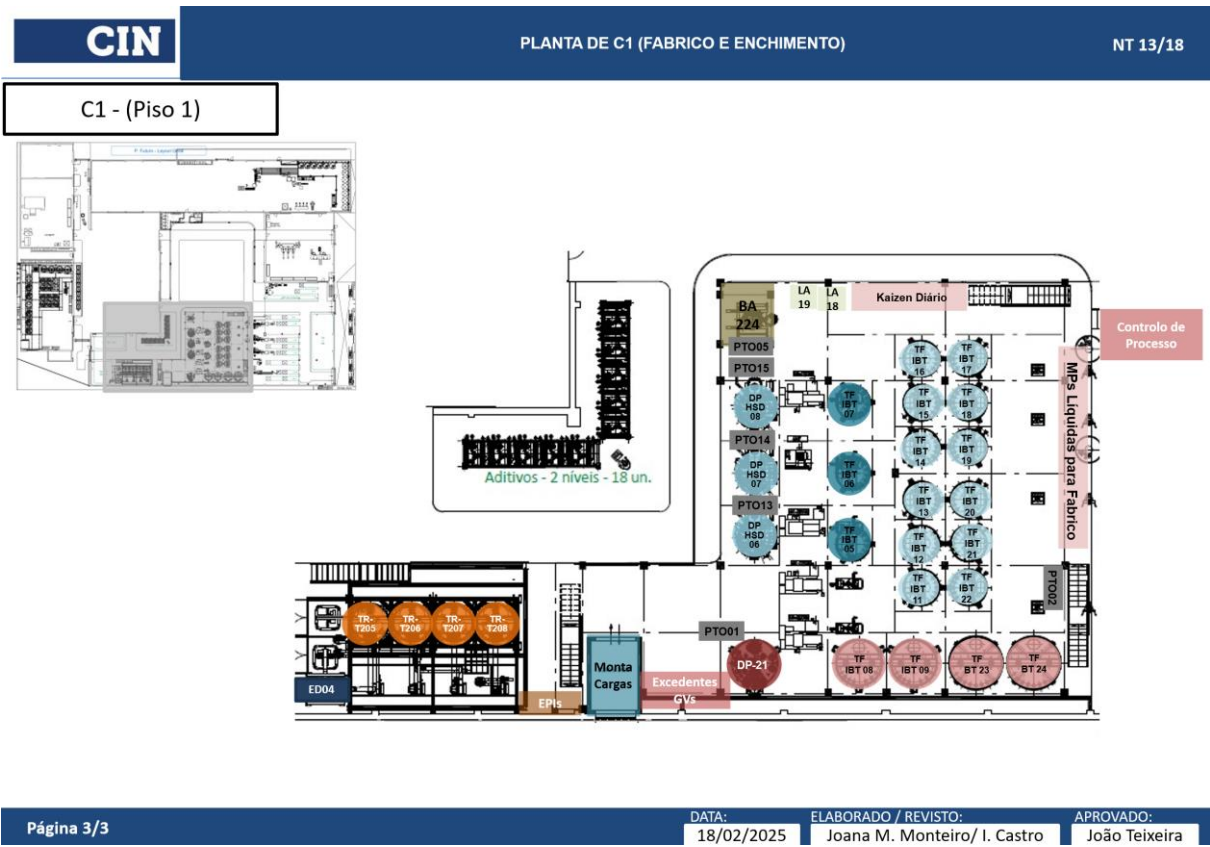


Appendix B: Swimlane of the Productive Process



Appendix C: Plant Layout of C1 Sector





Página 3/3

DATA:
18/02/2025

ELABORADO / REVISTO:
Joana M. Monteiro/ I. Castro

APROVADO:
João Teixeira

Appendix D: Sequence Chart

Sequence Chart					Sumário					
Máquina: Tipo setup: Notas:					Atividades		Valor			
					Operação					
					Movimentação	⇒				
					Armazenar	▽				
					Controlo	□				
					Espera	▷				
					Distância (m)					
					Tempo (s)					
Nº	Descrição operações	Distância (m)	Tempo (s)	○	⇒	▽	□	▷	Tipo operação	
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										

Appendix F: Cleaning and Verification Checklist - Small Volume Manufacturing

CIN		CHECKLIST DE LIMPEZA E VERIFICAÇÃO- FABRICO PV (INÍCIO DE TURNO)					CLK186 09-06-2025
Nº	TAREFA	___/___/___	___/___/___	___/___/___	___/___/___	___/___/___	
1	Verificar se os tanques móveis nas zonas de entrada da pré-mistura estão a verter. Em caso positivo: 1) Verificar se a válvula está mal fechada ou se a válvula está danificada. Caso a válvula esteja danificada: colocar um camlock e identificar o tanque com uma etiqueta "Válvula partida"; 2) Limpar o derrame.	☐	☐	☐	☐	☐	
2	Verificar que todas as MPs se encontram devidamente identificadas, com simbologia de perigo.	☐	☐	☐	☐	☐	
3	Verificar o quadro de ferramentas, o kit de limpeza e a existência de régua de moagem, placa de vidro e termómetro digital.	☐	☐	☐	☐	☐	
4	Verificar stock de panos, copos, frascos, tampas e latas para retirar amostras. Repor caso seja necessário.	☐	☐	☐	☐	☐	
5	Verificar stock de fitas de temperatura. Repor caso seja necessário. Stock mínimo: 5 fitas	☐	☐	☐	☐	☐	
6	Limpar os recipientes de limpeza da régua de moagem e substituir o diluente/água, se necessário.	☐	☐	☐	☐	☐	
7	Verificar se o conjunto de paletes escravas está conforme. Em caso negativo, colocar no exterior para recolha de resíduos e substituir por um novo.	☐	☐	☐	☐	☐	
8	Verificar stock de cartões. Repor caso seja necessário.	☐	☐	☐	☐	☐	
9	Verificar correto funcionamento dos sensores das garras nos três dispesores. Se não ok, comunicar à chefia e colocar identificação "NÃO UTILIZAR- EQUIPAMENTO AGUARDA REPARAÇÃO".	☐	☐	☐	☐	☐	
10	Trocar saco e limpar zona dodespoeirador.	☐	☐	☐	☐	☐	
Colaborador:							

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ELABORADO / REVISTO: Diogo Girão

APROVADO: João Teixeira

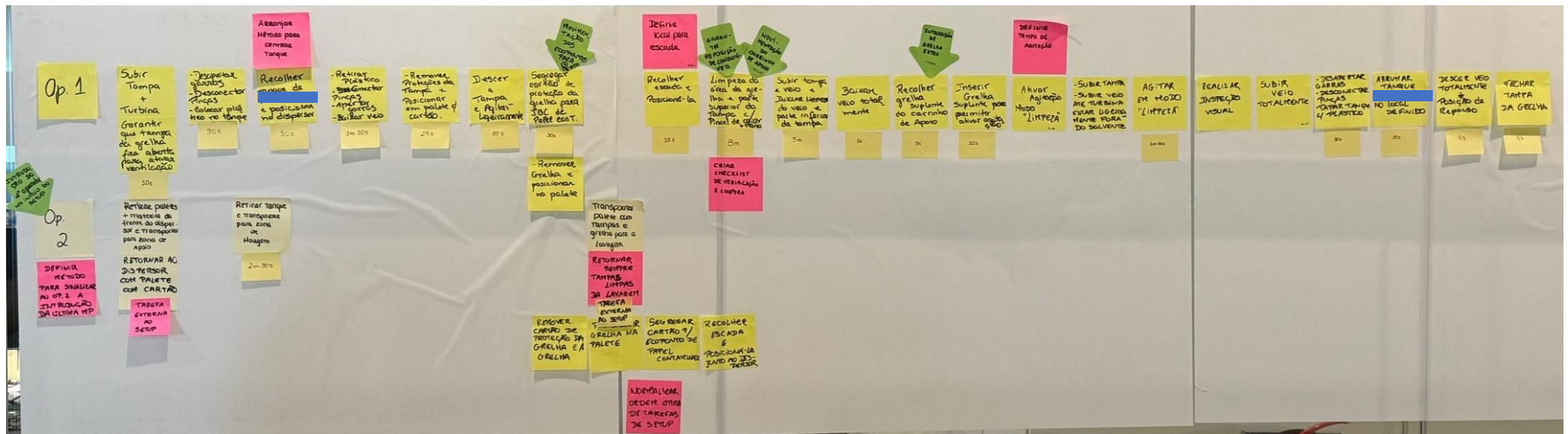
CIN		CHECKLIST DE LIMPEZA E VERIFICAÇÃO- FABRICO PV (FIM DE TURNO)					CLK186 09-06-2025
Nº	TAREFA	___/___/___	___/___/___	___/___/___	___/___/___	___/___/___	
1	Prensar cartão/papel contaminado.	☐	☐	☐	☐	☐	
2	Prensar plástico contaminado	☐	☐	☐	☐	☐	
3	Esvaziar, se necessário, os ecopontos de plástico contaminado, de cartão contaminado e de resíduos.	☐	☐	☐	☐	☐	
4	Verificar o quadro de ferramentas, o kit de limpeza e a existência de régua de moagem, placa de vidro e termómetro digital.	☐	☐	☐	☐	☐	
5	Verificar estado de água/diluente dos tanques de limpeza dos dispesores. Se necessário, substituir. Garantir que recipiente fica coberto.	☐	☐	☐	☐	☐	
6	Varrer/limpar a zona da pré-mistura. O lixo resultante deve ser colocado no ecoponto de derrames.	☐	☐	☐	☐	☐	
7	Verificar estado do cartão de proteção do chão. Se necessário, trocar.	☐	☐	☐	☐	☐	
8	Verificar estado de plásticos dos dispesores. Se necessário, trocar. <u>Colocar proteção do veio no momento da troca.</u>	☐	☐	☐	☐	☐	
9	Limpar escada de apoio e plataforma.					☐	
Colaborador:							

Página 2/2

ELABORADO / REVISTO: Diogo Girão

APROVADO: João Teixeira

Appendix G: SMED Workshop



Appendix H: Use and Cleaning of Dispersers Standard

CIN		UTILIZAÇÃO E LIMPEZA DOS DISPERSORES	
Responsável:	Operador de Fabrico	Setor:	C1F
		Máquina:	Dispersores Nave Central
		NT 68/24	
RISCOS	EPis		
ATENÇÃO  - Sobre-esforços - Queda de pessoas ao mesmo nível - Choque contra objetos e/ou pessoas - Choque contra estruturas fixas - Surdez - Entalamento - Enrolamento - Corte - Incêndio/explosão - Projeção de líquidos - Inalação, absorção, ingestão de substâncias perigosas/ CMR Para aceder a mais informação ver Portal > Aplicações > Sistema QAHS > Documentação > Análise e Avaliação de Riscos > CIN – Maia	      Filtro ABEK2 e Branco de Poeiras P3 Para aceder a mais informação ver Portal > Aplicações > Sistema QAHS > Documentação > Análise e Avaliação de Riscos > Listagem de Equipamentos de Proteção Individual (EPis) > CIN – Maia > Fábrica.		

Página 1/4

DATA:

16/06/2025

ELABORADO/REVISTO:

I. Castro, C. Carneiro / Diogo Girão

APROVADO:

J. Teixeira, A. Mendonça

CIN		UTILIZAÇÃO E LIMPEZA DOS DISPERSORES	
Responsável:	Operador de Fabrico	Setor:	C1F
		Máquina:	Dispersores Nave Central
		NT 68/24	
Início da Agitação			
Nº	Atividade	Fotografia	
A execução desta norma deve ser acompanhada pela consulta da NF_PT01/005.			
1	Subir a tampa e a turbina e ajustar os batentes, se necessário.		
2	Posicionar o tanque por baixo do dispersor, centrando-o.		
3	Puxar o plástico que se encontra no tanque para trás, prendendo-o com o elástico – o tanque deve ficar completamente descoberto, evitando o perigo do plástico enrolar na turbina.		
4	Baixar a turbina e a tampa do dispersor, com este em Modo Manual (0). Garantir que o perímetro da grelha de inserção de MPs fica dentro dos limites do tanque e que o veio fica centrado.		
5	Antes de descer a tampa totalmente, colocar as proteções da mesma, assegurando o correto encaixe com as peças posicionadoras (A) e o alinhamento da tampa nos três pontos de fixação (B).		
6	Apertar as garras através da manivela (A) existente na traseira do dispersor e, se necessário, ajustar a amplitude das garras através do manípulo (B). Garantir que não existe plástico a cobrir o cobre das garras nem o tanque na zona de contacto com as mesmas. 		
7	Conectar as pinças de ligação à terra. Esperar que a luz verde seja a única ativa.		
8	Fabrico com Receita Associada: O dispersor deve ser colocado em modo <i>Automático</i> (I) e devem ser seguidas as instruções no menu <i>Recipe</i>. Fabrico sem Receita Associada: O dispersor deve ser colocado em modo <i>Manual</i> (0), sendo possível definir a velocidade de rotação (rpm) do veio no painel de controlo.		

Página 2/4

DATA:

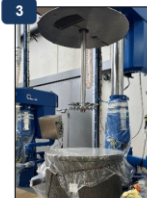
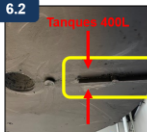
16/06/2025

ELABORADO/REVISTO:

I. Castro, C. Carneiro / Diogo Girão

APROVADO:

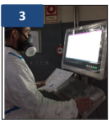
J. Teixeira, A. Mendonça

CIN		UTILIZAÇÃO E LIMPEZA DOS DISPENSORES		
Responsável:	Operador de Fabrico	Sector:	C1F	NT 68/24
		Máquina:	Dispensores Nave Central	
Fim da Agitação e Limpeza – Tempo objetivo: 21 min				
Nº	Atividade	Fotografia		
1	Em caso de modo Manual, definir a velocidade de rotação no botão giratório para 0 rpm. Aguardar que o movimento rotacional do veio termine. No caso de seguir uma receita (modo Aut.), a agitação é interrompida automaticamente após o tempo definido. Antes de iniciar a limpeza deve ativar-se o modo Manual.			
2	2.1. Subir a tampa e a turbina até a mesma estar ligeiramente fora do produto para sacudir a mesma, através de uma ligeira rotação do veio (garantir que ninguém se encontra junto ao veio).  2.2. Terminar subida da turbina, de forma a possibilitar a retirada do tanque.			
3	Abrir as garras através da manivela traseira. Desconectar as pinças de ligação à terra (luz fica vermelha). Tapar tanque com plástico de proteção e ajustar os batentes, se necessário. O 2º operador retira o mesmo para o local designado.			
4	Recolher tanque de  destinado à lavagem, e a lata com o pincel de cair e posicionar por baixo do dispersor, centrando-o.			
5	Seguir passos 3 e 6, descritos anteriormente na secção “Início da Agitação”.			
6	6.1. Garantir que o perímetro da grelha de inserção de MPs fica dentro dos limites do tanque, que o veio fica centrado. 6.2. Garantir ainda que o tanque aciona o sensor na traseira da tampa, tendo especial atenção no posicionamento de tanques de 400L.			
7	Baixar a turbina e a tampa, até ao nível necessário para retirar as proteções da tampa, que devem ser colocadas na paleta designada a ser encaminhada para a lavagem. Conectar as pinças de ligação à terra (luz fica verde).			
Página 3/4		DATA:	ELABORADO/REVISTO:	APROVADO:
16/06/2025		I. Castro, C. Carneiro / Diogo Girão		J. Teixeira, A. Mendonça

CIN		UTILIZAÇÃO E LIMPEZA DOS DISPENSORES		
Responsável:	Operador de Fabrico	Setor:	C1F	NT 68/24
		Máquina:	Dispensores Nave Central	
Fim da Agitação e Limpeza – Tempo objetivo: 21 min				
Nº	Atividade	Fotografia		
8	Baixar tampa totalmente e colocar a agitar.	10 		
9	Segregar cartão de proteção da grelha no ecoponto de papel contaminado. Recolher escada e posicionar na frente do dispersor.	12 		
10	Limpar área da grelha e parte superior envolvente da tampa, com pincel de cair, o solvente adequado e pano. Retirar a grelha e colocar na paleta designada a ser encaminhada para a lavagem.	14 		
11	Subir a tampa até ao máximo possível e subir ligeiramente a turbina.			
12	Lavar a tampa e a turbina com o auxílio do pincel de cair e pano, seguindo a mesma sequência descrita no ponto anterior. As pinças devem ser retirada antes de iniciar a limpeza com o pincel, impossibilitando o início da rotação do dispersor.			
13	Garantir que a tampa da grelha de inserção fica aberta durante a limpeza manual, para garantir o funcionamento da extração durante a limpeza.			
14	Ligar as pinças de ligação à terra e baixar a turbina até esta ficar mergulhada no solvente.			
15	Recolher grelha suplente do carrinho de apoio e colocar na tampa do dispersor. Agitar ligeiramente até 30 segundos.			
16	Subir a tampa e a turbina e agitar ligeiramente a turbina fora do solvente de limpeza (garantir que ninguém se encontra junto ao veio). ⚠	18 		
17	Subir completamente a turbina, abrir as garras, retirar a pinça de ligação à terra, colocar o plástico, remover tanque de [REDACTED] e retorná-lo à sua localização.			
18	Baixar o veio, deixando o dispersor na posição de repouso. Garantir que a tampa da grelha está fechada para parar o sistema de extração.			
Página 4/4		DATA:	ELABORADO/REVISTO:	APROVADO:
16/06/2025		I. Castro, C. Carneiro / Diogo Girão		J. Teixeira, A. Mendonça

Appendix I: Grinding Operation Standard

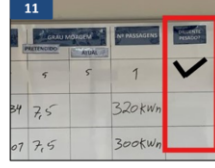
CIN			
OPERAÇÃO DE MOAGEM NAVE CENTRAL – PEQUENOS E GRANDES VOLUMES			
Responsável:	Operadores de Moagem	Setor:	Fabrico Nave Central
		Máquina:	ML10, ML12, ML23, ML25, ML27, ML28, ML31, ML34, ML35, ML36, ML37
			NT 20/24
RISCOS		EPIs	
 - Projeção de líquidos/ Projeção da mangueira - Surdez - Inalação, absorção ou ingestão de substâncias perigosas/ CMR - Incêndio e/ou explosão - Sobreesforços - Queda de pessoas/ objectos ao mesmo nível - Queda de objectos em altura - Choque contra objectos e/ou pessoas - Entalamento - Derrame - Queimaduras Para aceder a mais informação ver Portal > Aplicações > Sistema QAHS > Documentação > Análise e Avaliação de Riscos > CIN – Maia		 ¹ NOTA : Havendo pesagens a efectuar na <u>Zona da Pesagem</u>, se for o operador do moinho, o mesmo tem de utilizar os EPIs obrigatórios nessa zona de trabalho. Para aceder a mais informação ver Portal > Aplicações > Sistema QAHS > Documentação > Análise e Avaliação de Riscos > Listagem de Equipamentos de Protecção Individual (EPIs) > CIN – Maia > Fábrica.	
Página 1/9		DATA:	09/06/2025
		ELABORADO/REVISTO:	C. Carneiro, R. Gonçalves, J.M.Monteiro / D. Girão
		APROVADO:	A. Mendonça, J. Teixeira, J. Fernandes

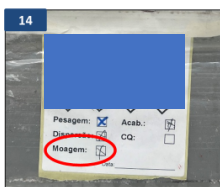
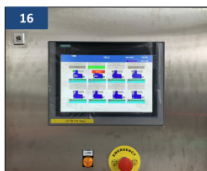
CIN			
OPERAÇÃO DE MOAGEM NAVE CENTRAL – PEQUENOS E GRANDES VOLUMES			
Responsável:	Operadores de Moagem	Setor:	Fabrico Nave Central
		Máquina:	ML10, ML12, ML23, ML25, ML27, ML28, ML31, ML34, ML35, ML36, ML37
			NT 20/24
Nº	Atividade	Fotografia	
1	No início do turno, a chefia indica o plano de trabalho para os moinhos.		
2	No caso dos 'Pequenos Volumes' é necessário apagar a informação do produto anterior no quadro dos moinhos e colocar as informações do produto a iniciar (código do produto, grau de moagem pretendido e consumo energético, se aplicável). Nota: a informação do produto anterior só deve ser apagada quando existir um produto seguinte.		
3	No HMI, efetuar os passos associados à receita. Ligar as conexões, ligar o moinho e fazer a purga. Colocar o cartão da SO na posição "Em curso" do moinho respetivo no quadro da Reunião Diária.		
Página 2/9		DATA:	09/06/2025
		ELABORADO/REVISTO:	C. Carneiro, R. Gonçalves, J.M.Monteiro / D. Girão
		APROVADO:	A. Mendonça, J. Teixeira, J. Fernandes

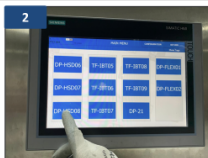
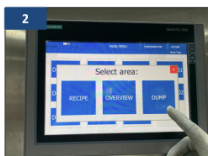
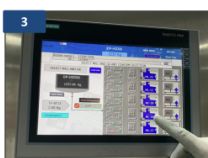
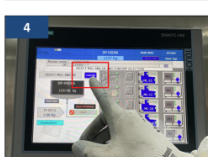
CIN		OPERAÇÃO DE MOAGEM NAVE CENTRAL – PEQUENOS E GRANDES VOLUMES		
Responsável:	Operadores de Moagem	Sector:	Fabrico Nave Central	NT 20/24
		Máquina:	ML10, ML12, ML23, ML25, ML27, ML28, ML31, ML34, ML35, ML36, ML37	
Nº	Atividade		Fotografia	
Pré-Lavagem dos Moinhos				
1	Recolher carrinho de apoio à moagem e quantificar na vasilha o agente de limpeza a utilizar. Garantir que a panela está fechada.			
2	Se o produto seguinte for da mesma natureza: Utilizar: - [] no caso de produtos à base de solvente - [] no caso de produtos à base aquosa Quantidades a aplicar: - Moinhos pequenos volumes: 70L (usar 50L se o produto seguinte for da mesma gama e da mesma cor); - Moinho com cuba de 45L: 50L; - Moinho com cuba de 90L: 100L. No caso de existir mudança de natureza, solvente para aquoso ou aquoso para solvente, necessário fazer 3 passagens: • Sequência de lavagem de Aquoso - Solvente: 50L de [] – 50L de solução aquosa [] – 50L de [] • Sequência de lavagem de Solvente - Aquoso: 50L de [] – 50L de solução aquosa [] – 50L de [] Nas lavagens com diluente, colocar pinça de ligação à terra no recipiente de destino. No caso de na MO do produto anterior estar incluída a etapa de lavagem de moinho, e for utilizada uma quantidade igual ou superior à quantidade de agente de limpeza a usar na pré-lavagem, não é necessário proceder à pré-lavagem. Na mudança de natureza, não é necessário passar o primeiro produto. Nota: No caso de o produto seguinte ser o mesmo, não é necessário realizar a lavagem. Nota: O operador tem de registar as quantidades gastas de solvente/água na CLK128.			
	Posicionar recipiente de resíduos respetivo junto ao moinho.			
Página 3/9 DATA: 09/06/2025 ELABORADO/REVISTO: C. Carneiro, R. Gonçalves, J.M.Monteiro / D. Girão APROVADO: A. Mendonça, J. Teixeira, J. Fernandes				

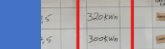
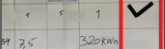
CIN		OPERAÇÃO DE MOAGEM NAVE CENTRAL – PEQUENOS E GRANDES VOLUMES		
Responsável:	Operadores de Moagem	Setor:	Fabrico Nave Central	NT 20/24
		Máquina:	ML10, ML12, ML23, ML25, ML27, ML28, ML31, ML34, ML35, ML36, ML37	
Nº	Atividade		Fotografia	
Pré-Lavagem dos Moinhos				
4	a) Colocar cana de pesca ligada ao moinho na vasilha com diluente/água. b) Colocar a saída do moinho no recipiente de resíduos respetivo. Ligar as pinças de ligação à terra no recipiente receptor, no caso de limpeza com solvente.		 	
5	Garantir que passador de saída está aberto. Ligar moinho e depois a bomba.			
6	Colocar na velocidade 5. (Apenas moinhos com cuba de 45L ou 90L)			
7	Aguardar que máquina escoe todo o resíduo.			
8	Desligar o moinho e depois a bomba.			
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CIN		OPERAÇÃO DE MOAGEM NAVE CENTRAL – PEQUENOS E GRANDES VOLUMES		
Responsável:	Operadores de Moagem	Setor:	Fabrico Nave Central	NT 20/24
		Máquina:	ML10, ML12, ML23, ML25, ML27, ML28, ML31, ML34, ML35, ML36, ML37	
Nº	Atividade	Fotografia		
Moagem – Pequenos Volumes				
1	Engatar o tanque seguinte ao moinho. Efetuar a purga do produto para o recipiente de resíduos até sair produto não contaminado (verificar visualmente). Sendo solvente, garantir que a pinça está ligada ao recipiente receptor.			
2	Afastar um pouco o carrinho com vasilha e transferir cana de pesca para tanque móvel com produto. Tapar o tanque com plástico. Colocar carrinho com vasilha no local definido e devidamente tapada.			
3	Ligar moinho e bomba.			
4	Reduzir a pressão do moinho, ajustando ao necessário e purgar até se verificar que começa a ser expelida apenas tinta.			
5	a) Moagem por passagens: posicionar um tanque vazio junto ao moinho e transferir mangueira de saída do moinho desde o recipiente de resíduos para o tanque vazio. b) Moagem por recirculação: transferir mangueira de saída do moinho desde o recipiente de resíduos para o tanque com produto.			
6	Colocar pinça eletrostática no tanque (verificar que a luz verde acende).			
7	Abrir passador da bomba para iniciar operação de moagem.			
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CIN		OPERAÇÃO DE MOAGEM NAVE CENTRAL – PEQUENOS E GRANDES VOLUMES		
Responsável:	Operadores de Moagem	Setor:	Fabrico Nave Central	NT 20/24
		Máquina:	ML10, ML12, ML23, ML25, ML27, ML28, ML31, ML34, ML35, ML36, ML37	
Nº	Atividade	Fotografia		
Moagem – Pequenos Volumes				
8	Arrumar o recipiente de resíduos no local respetivo. Nota: Sempre que recipiente de recolha de resíduos (diluente ou água) estiver cheio, colocar na zona de transição para que este possa ser recolhido pelo operador de apoio.			
9	Ao fim de 10/15 minutos verificar caudal, temperatura e pressão do moinho. Registrar na folha de medição dos caudais dos moinhos. Nota: É necessário verificar se o produto tem número mínimo de passagens. No fim da 1ª passagem, o tanque proveniente da fase de dispersão deve ser encaminhado para a lavagem.			
10	Pesar o diluente/água para a lavagem do moinho de acordo com o definido na MO. Recolher o carro designado para a pesagem nas balanças. Transferir o conteúdo do carro para a vasilha respetiva. Em caso de solvente, ligar a pinça de ligação à terra.			
11	Colocar no quadro de trabalho um "✓" no campo correspondente a "Diluente Pesado" e posicionar a vasilha com diluente/água pesado junto ao moinho devidamente tapada.			
12	Quando o produto estiver a menos de 1/3 do tanque móvel inclinar o tanque com o auxílio do "tilter" e posteriormente raspar o fundo do tanque.			
Página 6/9		DATA: 09/06/2025	ELABORADO/REVISTO: C. Carneiro, R. Gonçalves, J.M.Monteiro/ D. Girão	APROVADO: A. Mendonça, J. Teixeira, J. Fernandes

CIN		OPERAÇÃO DE MOAGEM NAVE CENTRAL – PEQUENOS E GRANDES VOLUMES			
Responsável:	Operadores de Moagem	Setor:	Fabrico Nave Central	NT 20/24	
		Máquina:	ML10, ML12, ML23, ML25, ML27, ML28, ML31, ML34, ML35, ML36, ML37		
Nº	Atividade		Fotografia		
13	Quando a tinta terminar:				
	a) Fechar o passador da bomba.				
	b) Transferir cana de pesca para a vasilha e ligar a pinça de ligação à terra.				
	c) Abrir passador de bomba para puxar todo o diluente/água, lavando moinho. O moinho deve ser mantido na velocidade máxima.				
	d) Desligar o moinho e a bomba.				
	e) Transportar o tanque vazio (se existir) + vasilha para a zona de lavagem, ambos devidamente tapados.				
13	f) Retirar filtro da bomba do moinho e proceder à sua limpeza de acordo com a natureza do produto.				
	Nota: No caso de bombas pneumáticas, garantir que a pressão é reduzida para evitar derrames.				
		Nos casos em que o solvente de lavagem do moinho não é suficiente, falar com o responsável do setor de forma a verificar se pode ser inserido solvente da parte do acabamento.			
14	Colocar tanque com o produto acabado na zona de tanques que aguardam acabamento e assinalar no rótulo de identificação a etapa da moagem com um "X".				
15	Atualizar o quadro de apoio aos moinhos, para tal retirar todas as informações exceto as correspondentes ao "Produto".				
16	Recolher a SO terminada e a seguinte, caso exista, finalizando no HMI a etapa de moagem da SO anterior e iniciar a limpeza do moinho de acordo com o definido na pré-lavagem dos moinhos para posterior arranque da SO seguinte.				
17	Colocar a SO finalizada no tabuleiro da etapa seguinte e o cartão na posição "Acabamento" do quadro de trabalho do Fabrico.				
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CIN		OPERAÇÃO DE MOAGEM NAVE CENTRAL – PEQUENOS E GRANDES VOLUMES		
Responsável:	Operadores de Moagem	Setor:	Fabrico Nave Central	NT 20/24
		Máquina:	ML10, ML12, ML23, ML25, ML27, ML28, ML31, ML34, ML35, ML36, ML37	
Nº	Atividade		Fotografia	
Moagem – Grandes Volumes				
1	Engatar as mangueiras que ligam o tanque ao moinho e o moinho ao tanque final.			
2	No PTO, selecionar o tanque e depois selecionar DUMP.			
3	Selecionar o moinho e o copo respectivo.			
4	Clicar em Confirm.			
5	Efetuar a purga através da mangueira que alimenta o copo para o recipiente de resíduos.			
6	Quando a purga estiver finalizada, engatar a mangueira de novo no copo.			
7	Após finalização do último DUMP associado a cada passagem, desconectar todas as mangueiras e verificar o estado de limpeza do grupo de envio.			
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CIN		OPERAÇÃO DE MOAGEM NAVE CENTRAL – PEQUENOS E GRANDES VOLUMES		
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Nº	Atividade	Fotografia		
Utilização do Quadro de trabalho dos moinhos da Nave Central				
1	No momento da recolha da nova SO no sequenciador:			
	1.1. Apagar a informação do produto anterior.			
	1.2. Escrever no moinho respetivo: 1) Código do produto; 2) Grau de moagem pretendido; 3) Nº Passagens (ex.:1)			
2	Sempre que se verificar o grau de moagem colocar o valor no campo "Grau de Moagem Atual".			
3	Quando iniciar uma nova passagem atualizar o campo "Nº Passagens".			
4	Após a pesagem do solvente de lavagem do moinho, colocar um "✓" no campo "Diluyente Pesado".			
5	No final de cada turno colocar o estado em cada produto (pré-amostra, continuar ou retirar).			
6	Quando a moagem estiver concluída escrever "Concluído" no campo "Estado", não apagando a informação até existir um novo produto para o moinho respetivo.			
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Appendix J: Excel Sheet for Calculating Nitrogen Injection Time

$$Q2=Q1 \sqrt{P2/P1}$$

P (HMI)	1,5	bar
P2 (absoluta)	2,5	bar
P1 (absoluta)	1,5	bar
Q1	30	m3/h (atualizar quando iniciar a dosificação)
P (manómetro)	1,5	bar

Q2	38,73	m3/h
-----------	-------	------

V (tanque)	9731	L
T (azoto)	15,08	min

Contagens intermédias

Volume expectável (L)		
1 min	645,50	L
2 min	1290,99	L
3 min	1936,49	L
4 min	2581,99	L
5 min	3227,49	L
6 min	3872,98	L
7 min	4518,48	L
8 min	5163,98	L
9 min	5809,48	L
10 min	6454,97	L

Appendix K: Fixed Tank Washing Operation Standard

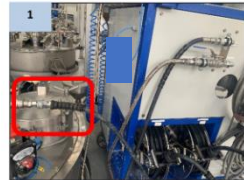
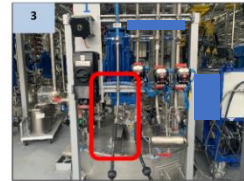
CIN		OPERAÇÃO DE LAVAGEM DE TANQUES FIXOS	
Responsável:	Operador de Fabrico - GV	Setor:	C1F
		Máquina:	LA-18/19
		NT 39/24	
RISCOS	EPIs		
ATENÇÃO  - Projecção de líquidos - Projecção de mangueiras - Queda de pessoas ao mesmo nível - Queda de pessoas em altura - Entalamento - Sobreexforços - Surdez - Inalação, absorção ou ingestão de substâncias perigosas / CMR - Incêndio e/ou explosão - Choques contra estruturas da máquina (cabeça) - Anoxia Para aceder a mais informação ver Portal > Aplicações > Sistema QAHS > Documentação > Análise e Avaliação de Riscos > CIN – Maia	      Filtro ABEK2 Para aceder a mais informação ver Portal > Aplicações > Sistema QAHS > Documentação > Análise e Avaliação de Riscos > Listagem de Equipamentos de Proteção Individual (EPIs) > CIN – Maia > Fábrica.		
Página 1/12	DATA: 12-06-2025	ELABORADO/REVISTO: C. Pinto, J.M.Monteiro, C. Carneiro / D. Girão	APROVADO: J.Teixeira, A.Mendonça, J.Fernandes

CIN		OPERAÇÃO DE LAVAGEM DE TANQUES FIXOS	
Responsável:	Operador de Fabrico - GV	Setor:	C1F
		Máquina:	LA-18/19
		NT 39/24	
Preparação da Lavagem			
Nº	Atividade	Fotografia	
1	Existem 5 tipos de lavagem de tanques fixos possíveis: IBTs / BTs – Lavagem de Base Aquosa IBTs / BTs – Lavagem de Base Solvente Nieman – Lavagem de Base Aquosa Nieman – Lavagem de Base Solvente DP-21 – Lavagem de Base Solvente A lavagem de Base Aquosa deve realizar-se com a máquina LA-18. (a) A lavagem de Base Solvente deve realizar-se com a máquina LA-19. (b)	 	
2	Após finalização do 'Dump para Enchimento', surge a indicação de que o tanque (IBT/BT/DP, HSD/Nieman) necessita de ser lavado – estado Dirty.		
3	Deve verificar-se o estado interior do tanque para confirmar a existência de produto no seu interior. Caso o tanque ainda tenha produto, este deve ser retirado e a situação comunicada de imediato à chefia.		
4	Após estarem garantidas as condições anteriores deve assegurar-se que as escotilhas para adição de sólidos e líquidos estão fechadas em todos os pontos de aperto. De notar que o tanque será sujeito a elevada pressão durante o processo de lavagem e que por isso este ponto deve ser completamente garantido.		
5	Seguidamente deve escolher-se a Flange (A ou B) destinada à inserção da lança de limpeza do braço da máquina de lavagem e abrir a tampa.		
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CIN		OPERAÇÃO DE LAVAGEM DE TANQUES FIXOS	
Responsável:	Operador de Fabrico - GV	Setor:	C1F
		Máquina:	LA-18/19
NT 39/24			
Preparação da Lavagem			
Nº	Atividade	Fotografia	
6	Mobilizar o equipamento de limpeza para próximo do tanque a lavar, para a zona definida. Caso se trate de uma limpeza de produtos de Base Aquosa deve ser utilizada a [] LA-18. Caso se trate de uma limpeza de produtos de Base Solvente deve ser utilizada a [] LA-19. Deve escolher-se a Dock Station apropriada as ligações das mangueiras, tendo o cuidado de não obstruir a passagem.		
7	Garantir que o cubo de resíduos apropriado se encontra debaixo do coletor, pousado no chão e que possui volume livre suficiente para albergar o resíduo que vai ser gerado na lavagem. Não deixar equipamentos de transporte (ex. porta-paletes) no local. <u>Suspensões contaminadas</u> (Resíduos Lavagem com água) – [] <u>Diluyente Sujo</u> (Resíduos Lavagem com diluyente) – [] [] Ligar a pinça de ligação à terra entre o tanque fixo e o IBC. A extensão entre o tanque e o IBC deve estar devidamente conectada e segura com fita adesiva. No caso do DP-21, IBT-08, IBT-09, BT-23 e BT-24 a ligação ao cubo de resíduos deve ser feita via bomba.	 	

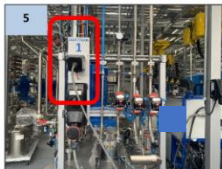
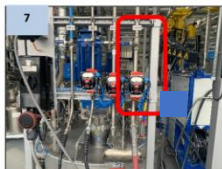
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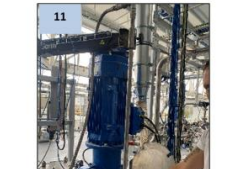
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CIN		OPERAÇÃO DE LAVAGEM DE TANQUES FIXOS	
Responsável:	Operador de Fabrico - GV	Setor:	C1F
		Máquina:	LA-18/19
NT 39/24			
Lavagem IBTs / BTs / DP-21 - Solvente (LA-19)			
Nº	Atividade	Fotografia	
1	Conectar a tubagem do azoto ao tanque.		
2	Conectar o azoto à Dock Station.		
3	Ligar o ar comprimido à Dock Station.		
4	Ligar a máquina à corrente.		

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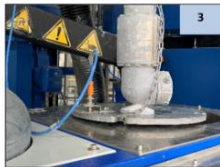
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12-06-2025ELABORADO/REVISTO:
C. Pinto, J.M.Monteiro, C. Carneiro / D. GirãoAPROVADO:
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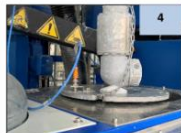
CIN		OPERAÇÃO DE LAVAGEM DE TANQUES FIXOS		
Responsável:	Operador de Fabrico - GV	Setor:	C1F	NT 39/24
		Máquina:	LA-18/19	
Lavagem IBTs / BTs / DP-21 - Solvente (LA-19)				
Nº	Atividade	Fotografia		
5	Ligar o sistema de comunicação de rede.			
6	Ligar a máquina. Deve premir-se a tecla de início até esta ficar verde e o sistema iniciar.			
7	Estabelecer a ligação de [] entre a Dock e a máquina.			
8	Ligar a pinça eletroestática (a luz deve passar de vermelha a verde).			
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CIN		OPERAÇÃO DE LAVAGEM DE TANQUES FIXOS		
Responsável:	Operador de Fabrico - GV	Sector:	C1F	NT 39/24
		Máquina:	LA-18/19	
Lavagem IBTs / BTs / DP-21 - Solvente (LA-19)				
Nº	Atividade	Fotografia		
9	Colocar o Nozzle em posição. Garantir que a correia está presa de modo a que, caso a conexão não esteja bem feita, o Nozzle não caia. No caso do DP-21, a ligação à flange B deve ser feita por dois colaboradores.			
10	O aperto da tampa do Nozzle deve estar bem feito (cruzado).			
11	Regular o braço extensor da lança para cima e projetá-lo depois para o interior da lança.			
12	Para reverter o processo a sequência tem de ser realizada pela ordem inversa. Nota: Sempre que é retirado o Nozzle tem de se fechar a Flange.			
13	O estado de limpeza do tanque deve ser verificado. Caso não esteja conforme, o processo de limpeza deve ser repetido.			
14	A máquina de limpeza deve ser arrumada na localização respetiva.			
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12-06-2025		C. Pinto, J.M.Monteiro, C. Carneiro / D. Girão		J.Teixeira, A.Mendonça, J.Fernandes

CIN		OPERAÇÃO DE LAVAGEM DE TANQUES FIXOS	
Responsável:	Operador de Fabrico - GV	Setor:	C1F
		Máquina:	LA-18/19
NT 39/24			
Lavagem IBTs / BTs – Aquosa (LA-18)			
Nº	Atividade	Fotografia	
1	Ligar a máquina à corrente.		
2	Ligar o sistema de comunicação de rede.		
3	Estabelecer a ligação de [] entre a Dock e a máquina.		
4	Ligar a máquina. Deve premir-se a tecla de início até esta ficar verde e o sistema iniciar.		
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		APROVADO: J.Teixeira, A.Mendonça, J.Fernandes	

CIN		OPERAÇÃO DE LAVAGEM DE TANQUES FIXOS	
Responsável:	Operador de Fabrico - GV	Setor:	C1F
		Máquina:	LA-18/19
NT 39/24			
Lavagem IBTs / BTs – Aquosa (LA-18)			
Nº	Atividade	Fotografia	
5	Colocar o Nozzle em posição. Garantir que a correia está presa de modo a que, caso a conexão não esteja bem feita, o nozzle não caia.		
6	O aperto da tampa do Nozzle deve estar bem feito (cruzado).		
7	Regular o braço extensor da lança para cima e projetá-lo depois para o interior da lança. Iniciar a Lavagem.		
7	Para reverter o processo a sequência tem de ser realizada pela ordem inversa. Nota: Sempre que é retirado o Nozzle tem de se fechar a Flange.		
PÁGINA 8/12		DATA: 12-06-2025	ELABORADO/REVISTO: C. Pinto, J.M.Monteiro, C. Carneiro / D. Girão
		APROVADO: J.Teixeira, A.Mendonça, J.Fernandes	

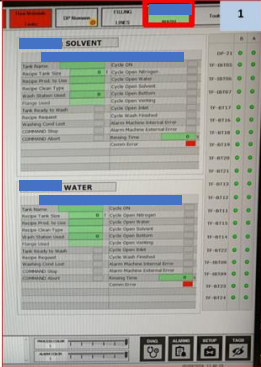
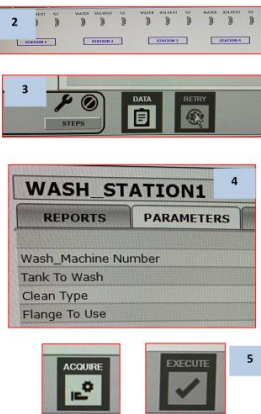
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Responsável:	Operador de Fabrico - GV	Setor:	C1F	NT 39/24
		Máquina:	LA-18/19	
Lavagem Nieman / HSD – Solvente (LA-19)				
Nº	Atividade	Fotografia		
1	Ligar a máquina. Deve premir-se a tecla de início até esta ficar verde e o sistema iniciar.			
2	Retirar o tubo de entrada para o Nozzle.			
3	Colocar a tampa e verificar que o sensor está ligado.			
4	Fazer as ligações do [] de do Azoto.			
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CIN		OPERAÇÃO DE LAVAGEM DE TANQUES FIXOS		
Responsável:	Operador de Fabrico - GV	Setor:	C1F	NT 39/24
		Máquina:	LA-18/19	
Lavagem Nieman / HSD – Aquosa (LA-18)				
Nº	Atividade	Fotografia		
1	Garantir que a pressão da máquina de Lavagem [] (LA-18) está regulada para 50 bar.			
2	Ligar a máquina. Deve premir-se a tecla de início até esta ficar verde e o sistema iniciar.			
3	Retirar o tubo de entrada para o Nozzle.			
4	Colocar a tampa e verificar que o sensor está ligado.			
5	Fazer a ligação de []			
Página 10/12		DATA: 12-06-2025	ELABORADO/REVISTO: C. Pinto, J.M.Monteiro, C. Carneiro / D. Girão	APROVADO: J.Teixeira, A.Mendonça, J.Fernandes

CIN

OPERAÇÃO DE LAVAGEM DE TANQUES FIXOS

Responsável:	Operador de Fabrico - GV	Setor:	C1F	NT 39/24
		Máquina:	LA-18/19	

Nº	Atividade	Fotografia
Operação de lavagem no SCADA		
0	Após todas as conexões estarem devidamente garantidas, o operador deve deslocar-se à sala de comando para dar início ao processo de limpeza no SCADA.	
1	No menu superior, selecionar WASH .	
2	Selecionar a STATION pretendida para a lavagem.	
3	Pressionar 'DATA' para definir os parâmetros.	
4	Preencher os parâmetros: - Wash_Machine Number - Tank to Wash - Clean Type - Flange to Use Nota: Existem 3 modos de lavagem (SOFT, MEDIUM e HARD). Devem ser selecionados consoante os parâmetros seguintes: - Tanques HSD07 e IBT06: selecionar modo SOFT. - Tanques BT11/12/13/14/15/16/17/18/19/20/21/22: - Se o produto a lavar for de natureza solvente e incolor: selecionar SOFT. - Selecionar MEDIUM para os restantes produtos de natureza solvente. - Tanques DP21/IBT08/IBT09/BT23/BT24: selecionar HARD. Para os tanques restantes e para produtos de natureza aquosa, deve ser selecionado o mais adequado. Nota: Flange A corresponde ao lado direito do tanque, enquanto que a Flange B corresponde ao lado esquerdo do tanque.	
5	Premir a tecla ACQUIRE e depois a tecla EXECUTE .	

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CIN

OPERAÇÃO DE LAVAGEM DE TANQUES FIXOS

Responsável:	Operador de Fabrico - GV	Setor:	C1F	NT 39/24
		Máquina:	LA-18/19	

Nº	Atividade	Fotografia
6	Premir a tecla IDLE e de seguida a tecla EXECUTE .	
7	Verificar que o botão IDLE passa a verde e i "RUNNING".	
8	Nota: Se estiver algum processo ativo em sistema no tanque que vai ser lavado surge a mensagem <i>waiting</i>. Esta situação deve ser resolvida para que se possa dar início ao processo de lavagem	

DATA:

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