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# An Analysis of No-Cost Solutions for Toxic Waste Reduction in a Commercial Chemistry Plant †

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## 1. Introduction

With increasing environmental and public health challenges, the problem of reducing toxic waste in industry is becoming not only an important environmental task, but also an important aspect of economic efficiency. These substances may be poisonous, corrosive, flammable, explosive, or may have other hazardous properties. The types of toxic waste can be diverse, encompassing chemical, biological, radioactive, and other hazardous materials. By understanding these two key dimensions, we can assess the benefits to both the environment, public health, and the operational efficiency of industrial companies.

Investment in modern technology and waste management strategies is the key to the future of sustainable industrial development and provides the foundation for building a more responsible and greener society. By using modern methods of recycling, recovering raw materials, and cleaning up emissions, industry can significantly reduce its negative impact on the environment, allow for greater public awareness of the problem of environmental pollution, and the promotion of sustainable production and consumer practices. Educating and informing the public about the consequences of toxic pollution and encouraging a change in consumer habits can contribute to long-term environmental protection.

## 2. No-Cost Solutions Applied within the Company

By their very name, no-cost solutions are the most popular initial actions to launch in the industry. These are usually topics concerning organizational matters, standards, and training. Industrial automation matters in this time of optimizing software; its operations or sequences also fall into the organizational framework if, and only if, the change to the software does not require interference with the mechanical infrastructure of the production line.

An American company specializing in household chemicals launched a 'zero waste' project in one of its factories. The main objective of this project was to reduce the cost of the toxic waste generated, which increased significantly between 2021 and 2023. A line mass-producing bottles filled with pipe-cleaner for the consumer market using 4 million liters of toxic substance per month was analyzed. It is a complete production line that encompasses the entire process from raw materials to finished products, including manufacturing, processing, assembly, testing, and packaging.

The products manufactured are 0.5 L and 1 L bottles of pipe-cleaning agent. The agent contains hazardous substances, i.e., 15% NaCl (sodium hypochlorite) and 8% NaOH (sodium lye). The residue is a strictly formulated concentrate. Its specification is proprietary.

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The bottles are made of high-density polyethylene (HDPE). They are closed with safety caps equipped with a special mechanism to make it difficult for children to open the packaging.

This line was equipped with eight segments based on different technological processes. These segments are as follows:

- SKID—an assembly consisting of dispensers, pump mixers, and tanks.
- Surge tank—the target tank where the final formulation is created.
- Filler with capper—a machine that pours the previously prepared formula into the target packages, which are 0.5 L and 1 L bottles made of HDPE with high chemical resistance.
- Plasma machine—responsible for reducing electrostatic charges accumulated on the bottles.
- Labeling machine—its task is to apply wax labels to the bottles using water-based glue.
- Carton folding machine—is responsible for unfolding the carton previously prepared by the supplier and shaping it to fill it into finished products.
- Manual packing zone—this is a conveyor network of eight open points from which the finished product (bottle) is taken and packed into a carton.

Its capacity was expressed in terms of pouring speed, at 150 L/min.

## 3. Identification of the Types and Quantities of Toxic Waste Generated by the Selected Production Line

In the production line shown, there is a risk of generating production waste at each stage of the process. Each module generates controlled waste as well as uncontrolled waste. Controlled waste refers to any quality test that results in liquid waste or waste enclosed in packaging (Table 1). Uncontrolled waste is that which results from the inadequate performance of machinery and equipment, which amounts to the creation of all kinds of products that do not comply with quality.

**Table 1.** Summary of controlled waste [kg] for a production line generated during 24 h of production.

| Bottle Format | Process Module | | | | | | |
|---|---|---|---|---|---|---|---|
| | SKID | Surge-Tank | Pouring Machine/ Capper | Plasma Machine | Labeling Machine | Case Folding Machine Packing Zone Palletizing Machine | Total |
| | Controlled Waste [kg] | | | | | | |
| Bottle, 0.5 L | 116.5 | 93 | 384 | 3 | 4.5 | 0 | 601 |
| Bottle 1 L | | | 768 | 6 | 9 | 0 | 992.5 |

Uncontrolled waste results from the process itself or human errors. In order to identify it, it is necessary to monitor the process and carry out analyses that confirm the data and allow appropriate conclusions to be drawn.

To assess the scale of uncontrolled waste in a process, it is necessary to collect all the activities and operations performed on a given machine. On all modules, an analysis of the operation of the entire machine infrastructure was carried out, taking into account the performance of its components and the operational activities that are performed by humans.

## 4. Solving the Problems of Toxic Waste Generation

In the SKID line area, with the current problems of toxic waste generation, one of the proposed solutions was to update the program dedicated to the production of concentrates. The delivery of a second raw material of 1.8 kg with a tolerance of +/−10% was analyzed. The system was based on the analysis of a bulk flow meter upstream of the concentrate tank itself, while a so-called 'timer' was set for the bucket rotor pumps, i.e., a preset running time in a specific sequence in the program. Based on the preset start-up and shut-down times, the flow meter collected data correlated with the pump settings. If the flow meter

approached the preset quantity programmed for a specific time and the pump shutdown occurred too late, an overdose of raw material occurred. This resulted in the concentration of the second raw material exceeding tolerance limits, rendering the prepared concentrate unusable and classified as waste. By analyzing the duration of the pump start-up, valve opening and raw material delivery, it was possible to improve the delivery efficiency, resulting in a dose deviation of max. +/−2%, which was within the specification tolerance. After confirming the efficiency of the optimized program operation, it was necessary to prepare a new MOC ('management of change') procedure, which enabled the new program to be put into operation after testing.

Another no-cost activity on this line was to carry out tests to attempt to wash labels from bottles that had been defined as waste in terms of poor label positioning that was out of quality tolerance. For this purpose, water tanks with water not exceeding 30 °C were prepared, in which 20 bottles were placed in an upright position with the tanks not exceeding the height of the necks of these bottles. After the bottles had been conditioned in the water for 20 min, with the help of a cotton cleaner, the bottles were dried and the peeled labels from the bottles were left in the water. The glue reacted with the warm water to lose its viscosity, allowing the labels to peel easily off the walls.

Another activity in this process area was an attempt to wash off the printed production date on the 1 L bottles. The chemical used for the service cleaning of the printer head was used for this purpose. A dust-free cleaning cloth on which the agent was applied allowed the poorly printed use-by date to be washed off the surface of the bottle, and in a subsequent step it could be re-printed. The development of measures to start the process of washing off the labels as well as the production date required the creation of procedures, instructions, and staff training.

## 5. Conclusions

The project to turn back the formula, i.e., to keep it as much as possible in the technological process, actually gave an environmental benefit to the world as well as an economic benefit to the company. The measures taken included the optimization of technological processes and the introduction of more efficient resource management methods. As a result, the company not only reduced its emissions of hazardous substances, but also reduced costs related to waste management and pollution penalties.

In summary, the project to reduce the production of hazardous substances emitted into the environment has not only produced the desired environmental results, but has also brought real economic benefits to the production facility, inspiring further sustainability efforts. As a result, the company has become more competitive in the market, gained recognition among customers and business partners, and contributed to the protection of the environment locally and globally. This shows that investing in ecology and sustainability is not only ethical, but also financially viable.

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