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SYNERGIC EFFECT OF "GREEN" CHEMISTRY AND LEAN PRODUCTION

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Abstract

In the modern Russian industry, the problem of environmental friendliness of production and the rational use of material resources is especially relevant. Inefficient organization of production processes poses a threat to the ecosystem of the industrial zone. The purpose of the study is to develop proposals for the integration of the concepts of "green" chemistry and lean production to minimize production losses in chemical technological systems. The research methodology for production losses of chemical technological systems is based on the principles of "green" chemistry and the concept of lean production. A dialectical and systemic approach, methods of cause-effect relationships, and structural-functional analysis are used to achieve this goal. Determination of possible losses by types of chemical production is carried out based on logical and mathematical calculations of the resource intensity of production, identification of extrema, and correlation dependences between the parameters under study. The article proposes integrating the principles of "green" chemistry and lean manufacturing to form a unified system with the emergence effect "Green lean manufacturing". A methodological approach to assessing possible losses of material resources based on the determination of the extremes of the resource intensity of production is proposed. A close linear dependence of the specific material consumption of production and the added value received from a production unit is revealed.

Keywords: Added value, green chemistry, lean production, production losses, resource intensity, synergy effect

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1. Introduction

The problem of saving and rational use of material production resources is essential for the production systems' life cycle's environmental friendliness. Excessive use of resources occurs as a result of the ineffective organization of production processes and outdated technologies, which in modern realities pose a high threat to the ecosystem.

Petrochemical industries, extracting and technologically transforming natural resources, and the products used after operation, return to the environment and irrecoverable waste. At the same time, a systematic approach to managing the consumption of material resources makes it possible to increase the resource saving of production by optimizing stocks and consumption of raw materials, components, and energy sources.

2. Problem Statement

As statistics show, over the past 30 years, global resource consumption has doubled, and therefore a continuation of this trend will lead to another doubling of resource consumption by 2050.

In this regard, the need to consider production losses from the perspective of the principles of lean production seems promising. Lean production is aimed at eliminating the loss of all types of resources: material, time, financial. At the same time, for green production, the most important is the loss of material resources extracted from the environment and harming it in the production process.

3. Research Questions

It should be noted that the discussion of the problem of synthesis of the concepts of "green" chemistry and lean production in domestic and foreign literature and practice is extremely rare. This promising direction in our opinion, has not been fully studied to date. It is clear that lean manufacturing, whose goal is to eliminate waste, can become a vector for developing "green" production systems. Attempts have been made to describe the principles of eliminating losses in lean manufacturing from the perspective of environmental protection in the works of Chen et al. (2019); Koh et al. (2019); Shinkevich et al. (2018); Siegel et al. (2019). The authors studied approaches to reducing losses in global supply chains from overproduction by using lean manufacturing principles, introducing digital technologies as a moderator of the influence of lean manufacturing practices on improving operational efficiency, and others.

Research in the field of models of rational production and consumption, environmental sustainability of European production, circular economy in production planning belongs to such authors as Aliev & Grazion (2018); Braganca et al. (2019); Le Tellier et al. (2019); Sala et al. (2020); Suzanne et al. (2020); Tortorella et al. (2019); Zhou et al. (2019).

The directions of the impact of the loss of material resources on the ecosystem and a decrease in the share of value added in the production of products, taking into account the specifics of chemical industries (Shinkevich et al., 2016). There is a noticeable scientific interest in algorithms for optimizing joint production planning and maintenance in a global resource constraint (Boufellouh & Belkaid, 2020).

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The principles of green chemistry take into account areas related to the elimination of production losses. In this regard, losses in lean production are considered in combination with the efficiency of using material resources and the impact on the environment (Schmidt, 2018; Shen, Han, 2018).

4. Purpose of the Study

The aim of the study is to substantiate the feasibility and develop proposals for integrating the concepts of "green" chemistry and lean production to minimize production losses in chemical technological systems. The need for research is due to the relevance of the development of organizational tools for managing the consumption of material resources of production and the reduction of irrecoverable losses.

5. Research Methods

The research methodology for production losses of chemical technological systems is based on the principles of "green" chemistry and the concept of lean production. To achieve this goal, a dialectical and systematic approach, methods of cause-effect relationships and structural-functional analysis were used. Determination of possible losses by types of chemical production was carried out on the basis of logical and mathematical calculations of the resource intensity of production, identification of extrema and correlation dependences between the parameters under study.

6. Findings

A logical-structural study of the classification and causes of the origin of production losses in the projection of the principles of "green" chemistry and lean production made it possible to establish causal relationships. The development of the concepts of "green" chemistry and lean production should be interconnected, taking into account the goals of minimizing the impact on the ecosystem ("green" chemistry) and optimization of resources and time for production, subject to ensuring the quality and minimum cost of production (lean production). At the same time, the concept of lean manufacturing provides for meeting the needs of customers for production or services by any available methods, which contradicts the principles of "green" chemistry. For example, the logistics concept "Just In Time", aimed at frequent deliveries in small quantities, provides, on the one hand, an optimal inventory management system and resource efficiency, on the other hand, contributes to an increase in the pollution of transport media and additional consumption of fuel resources. Thus, this lean production tool is questioned as minimizing the impact on the ecosystem.

Undoubtedly, the concepts of "green" chemistry and lean production have a similar philosophy and can be developed as a single system. The implementation of the principles of these concepts can give a synergistic effect, i.e. lead to an increase in production efficiency as a result of the integration of private concepts into a single system (table 1).

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Table 1. Formation of a unified concept "Green Lean Production" with the effect of emergence (compiled by the author using [Siegel et al., 2019])

Form of scientific knowledge	"Lossless" production organization concepts		Unified system with emergence effect
	"Green" chemistry	Lean production	"Green Lean Production "
Concept philosophy	Cost-effective production with minimal impact on the ecosystem and highly closed technological processes	Cost-effective production with minimum waste of all types of production resources and maximum customer satisfaction	Cost-effective production with minimal resource consumption and impact on the ecosystem while ensuring product quality and customer satisfaction
Limitations of the concept	Minimum consumption of material resources; reducing the load on the ecosystem; reduction of production costs	Minimum consumption of material resources; saving time for production; reduction of production costs	Minimum consumption of all production resources; reducing the load on the ecosystem; reduction of production costs

A single concept "Green Lean Production" with the effect of emergence combines two resource-saving philosophies that impose additional restrictions on each other, but have prospects for further theoretical development and practical use. The concept of lean production implements an important principle of "green" chemistry – resource conservation, but it does not assess the impact on the ecosystem.

The problem of irrational use and loss of raw materials and fuel and energy resources in the chemical industry is quite acute. Table 2 summarizes the data on the resource intensity of products of 85 enterprises of the Republic of Tatarstan for 12 subspecies of chemical production and production of rubber and plastic products. For each type of production, the minimum and maximum values of the resource intensity of production are presented. The resource intensity of production is understood as the specific consumption of all types of materialized resources required for the manufacture of a unit of production, which is expressed as a percentage or value units of resources used in the volume of output.

The resource intensity of the products of enterprises of the same types of chemical production differs significantly, which, in our opinion, is the basis for a deeper study of the level of resource consumption. The difference between the minimum and maximum values of the resource intensity of production can be considered as a loss of resources or a reserve for reducing their specific consumption. The extreme values of the resource intensity indicator were determined by the method of statistical processing of an array of data on enterprises and types of the above indicated chemical industries for the period from 2015 to 2019.

For example, in the production of plastic plates, strips, pipes and profiles, the enterprises of LLC "Polimerholodtekhnika", LLC "Ecopet", LLC "Tatneft-Presscomposit", CJSC "Danaflex", LLC "KZPM", LLC "Safplast", LLC "Polipak were investigated", LLC "Dekafom", LLC "Tekhstroy", LLC "Tatteploizolyatsiya". It was established that the minimum resource intensity for this type of production is 0.434 rubles of resources per unit of production, and the maximum resource intensity is 0.848. Thus, the excess of the maximum value over the minimum value reaches 95%, and the difference between them is

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defined as 0.414 rubles of resources per unit of production. Thus, the conditionally optimal value of resource intensity in the production of plastic plates, strips, pipes and profiles can be taken as 0.343, and the difference of 0.414 can be considered as possible losses of resources or as a reserve for reducing their specific consumption for OOO "Tatteploizolyatsiya" and OOO "Tekhstroy". Accordingly, for other enterprises, the value of possible resource losses will be equal to the difference between the current value of resource intensity and the minimum possible value of resource intensity by type of activity.

Table 2. Extremes of the resource intensity indicator and possible losses of resources of chemical industries of the Republic of Tatarstan in 2016-2019 (compiled by the author on the basis of data from the official websites of enterprises)

Type of activity of chemical production	Resource intensity of production, rubles		Potential loss of resources	
	minimum value	maximum value	Exceeding the maximum value over the minimum,%	Difference between maximum and minimum value
Industrial gas production	0.341	0.432	126.8	0.091
Production of basic inorganic chemicals	0.453	0.749	165.5	0.297
Production of basic organic chemicals	0.438	0.603	137.7	0.165
Production of plastics and synthetic resins in primary forms	0.447	0.744	166.4	0.297
Production of paints and varnishes based on polymers	0.748	0.984	131.6	0.236
Production of soap and detergents, cleaning and polishing products	0.490	0.502	102.5	0.012
Production of perfumery and cosmetics	0.547	0.682	124.7	0.135
Production of rubber tires, tires and tubes; restoration of rubber tires and tires	0.578	0.760	131.4	0.181
Production of plastic plates, strips, pipes and profiles	0.434	0.848	195.3	0.414
Production of plastic products for packaging goods	0.568	0.673	118.5	0.105
Production of plastic products used in construction	0.466	0.914	195.8	0.447

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Production of other chemical products	0.405	0.664	163.9	0.259

Reducing the resource intensity of production, just like reducing the loss of resources, increases the added value of production. In turn, the share of value added in the volume of output, in our opinion, characterizes production efficiency: how much value added is created by a given enterprise in the production of a unit of output. The study revealed an inverse rather close relationship between the material consumption of products and production efficiency (specific value added) with a correlation coefficient of -0.78. As the specific consumption of material resources decreases, the added value of the enterprise increases.

A different situation is observed in the system "Fuel and energy consumption of products - Value added per unit of production". There is practically no interrelation of these parameters for the set of the surveyed enterprises – the correlation coefficient is 0.26. This contradicts the theory of energy efficiency and, probably, is explained in this case by the relatively small value of energy resources in the cost of production compared to the dominant factor - raw materials and materials, as well as indirect impact.

This situation requires a more detailed study. Nevertheless, for the aggregate of enterprises, the relationship between the absolute values of fuel and energy resources and the cost of production is straight linear with a correlation coefficient of 0.98.

7. Conclusion

Thus, the article reveals the theoretical aspects of energy and resource efficiency of enterprises, the processes of formation of abnormal losses and production waste. We see the solution to the problem of resource conservation using the tools of the lean manufacturing concept, adapted to the principles of "green" chemistry. On the example of the analysis of an array of chemical production enterprises, the problem of inefficient use of resources with the possible determination of reserves for increasing resource efficiency is formed.

Undoubtedly, the variation in the values of the resource intensity of production can be due to many factors, including the difference in the range of products, the level of technology, methods of organizing the procurement of raw materials, etc. Nevertheless, the proposed approach to determining the optimal value of specific resource consumption based on the analysis of enterprises of identical industries can be used for the initial assessment of the resource efficiency of production and the search for solutions to increase it.

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