REVISTA CÁTEDRA

Relevance and prospective study of the chemical professional in the national, regional and current world scenario

Estudio de pertinencia y prospectivo del profesional químico en el escenario nacional, regional y mundo actual

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(Received on: 06/02/2024; Accepted on: 15/03/2024; Final version received on: 15/06/2024)

Suggested citation: Almachi-Villalba, D., Yépez-Padilla, M. Espinel-Armas, E. y Alcívar-León, C. (2024). Relevance and prospective study of the chemical professional in the national, regional and current world scenario. *Revista Cátedra, 7*(2), 40-59.

Abstract

This research aimed to highlight the importance of chemical professionals at national, regional and global levels; for this, a systematic review was conducted to demonstrate the capabilities of chemical professionals who are closely linked to regulations set by the Ecuadorian Institute of Standardization (INEN), Codex Alimentarius, among others that govern the operations of companies to research and develop products of various economic sectors with quality. Regarding the linkage of chemical professionals in a global context, the literature review made it possible to align the profile of the chemical professional with the Sustainable Development Goals (SDGs), providing the basis for curriculum design or professional training content. On the other hand, surveys were conducted to representatives of companies in the industrial sector related to chemistry to consult cleaner production activities in the framework of the SDGs, where waste recycling stood out with 30.43%. To deepen the responses, focus groups were conducted, where company representatives expressed a clear interest in closer ties with academic institutions to access updated knowledge, continuous training and advice. In addition, they highlighted the need for chemical professionals to possess leadership, teamwork and effective communication skills. These findings show the need to strengthen collaboration between industry and academia to improve the implementation of sustainable practices in companies where chemical professionals have a relevant role in solving environmental challenges and promoting sustainable practices in various economic sectors.

Keywords

Curriculum design, relevance study, Sustainable Development Goals, chemical professionals.

Resumen

La presente investigación tuvo como objetivo destacar la importancia de los profesionales químicos a nivel nacional, regional y global; para esto, se realizó una revisión sistemática para evidenciar las capacidades de los profesionales químicos que están estrechamente vinculados a normativas señaladas por el Instituto Ecuatoriano de Normalización (INEN), Codex Alimentarius, entre otras que rigen las operaciones de empresas para investigar y desarrollar productos de diversos sectores económicos con calidad. Respecto a la vinculación de los profesionales químicos en un contexto global, la revisión bibliográfica permitió alinear el perfil del profesional químico con los Objetivos de Desarrollo Sostenible (ODS), proporcionando la base para el diseño curricular o contenidos de formación profesional. Por otra parte, se realizaron encuestas a representantes de empresas del sector industrial afines a la química para consultar actividades de producción más limpia en el marco de los ODS, donde el reciclaje de residuos destacó con un 30.43%. Para profundizar en las respuestas se realizaron grupos focales, donde los representantes de empresas expresaron un claro interés en estrechar lazos con las instituciones académicas para acceder a conocimientos actualizados, capacitación continua y asesoramiento. Además, resaltaron la necesidad de que los profesionales químicos posean habilidades de liderazgo, trabajo en equipo y comunicación efectiva. Estos hallazgos evidencian la necesidad de fortalecer la colaboración entre industria y academia para mejorar la implementación de prácticas sostenibles en las empresas donde los profesionales químicos tienen un rol relevante en la resolución de desafíos ambientales y en la promoción de prácticas sostenibles en diversos sectores económicos.

Palabras clave

Diseño curricular, estudio de pertinencia, Objetivos Desarrollo Sostenible, profesionales químicos.

1. Introduction

Higher education denotes an important responsibility in the face of emerging challenges such as climate change, globalization and technology in society. The problem in higher education in terms of professional training relevant to social needs lies in a disconnection between the academic curriculum and the changing demands of society. Therefore, the relevance of the careers should be reviewed and updated on an ongoing basis, and thus ensure that academic programs are aligned with reality and that they are executed around theories and pedagogical models relevant to reality and the social environment.

The analysis of the role of the chemical professional in the current context takes into account macro guiding documents such as the Sustainable Development Goals (SDGs), Constitution of the Republic of Ecuador, National Development Plan for the New Ecuador 2024-2025, among others. In the local context, the Development and Land Management Plan 2019-2023 of the Prefecture of Pichincha, an area of geographic influence due to the location of the Faculty of Chemical Sciences of the Central University of Ecuador, is considered. On September 25, 2015, world leaders agreed on the "Sustainable Development Goals (SDGs) to be achieved by 2030, these global goals are directly linked to eradicating poverty, protecting the planet and ensuring prosperity for all" (UN, 2023, p. 21). In this sense, "scientific research and investment in new technologies, in strategic industrial sectors generate an environment of competitiveness, sustainable economic development that promotes poverty eradication" (Haro-Sarango et al., 2023, p. 12). In addition, the chemical professional can promote innovation and the implementation of sustainable technologies, such as clean production, recycling of materials and efficient resource management, and the implementation of environmentally friendly practices in various industrial sectors.

Particularly, when analyzing the SDGs in accordance with the main industries of the country, where the chemical professional would have influence, his contribution is linked to sectors such as Agroindustrial (Agriculture, livestock, forestry and fishing), mining and quarrying and manufacturing industries, and therefore, directly with economic growth (SDG8), which in parallel correlates with the SDGs such as end of poverty (SDG1), zero hunger (SDG2), industry - innovation and infrastructure (SDG9).

The chemical professional plays an essential role in protecting the planet, specifically in critical areas such as clean water and sanitation (SDG6), where their expertise in wastewater treatment and water purification contributes to ensuring access to safe drinking water for communities. With regard to climate action (SDG13), chemists work on developing renewable energy technologies and reducing emissions, thus addressing the challenges of climate change. Furthermore, in the area of affordable and clean energy (SDG7), chemical professionals are involved in the research and application of methods to produce energy sustainably and efficiently. In the preservation of underwater life and terrestrial ecosystems (SDG14 and SDG15), chemists play a key role in pollution management, the development of biodegradable materials and the conservation of biodiversity, contributing to protecting life in the oceans and on land (UN, 2023).

Therefore, the objective of this research focuses on highlighting the importance of chemical professionals at national, regional and global levels based on the requirements of the employer sector.

As for the content of the manuscript, the methodological procedures applied to fulfill the purpose of the research are presented, followed by the main results of the focus groups and the survey applied to representatives of the industrial sector of incidence of the chemical professional and possible labor niches, to finally establish the conclusions of the study.

1.1 Methodology

1.2 Approach

The study is aligned with the theoretical assumptions that govern the sociocritical paradigm, according to the articulation of qualitative and quantitative data, to better interpret the context and requirements of the chemical professional in the current local and national scenario. The research level is descriptive-cross-sectional.

It was based on the bibliographic analysis of relevant normative and regulatory elements, such as the declaration of SDGs, Constitution of the Republic of Ecuador, Development and Land Management Plan 2019-2023 of the Prefecture of Pichincha, Development Plan for the New Ecuador 2024-2025 among others, to determine the gaps or dilemmas of the profession that require addressing from higher education and clarify the structuring cores for the formation of the chemistry professional and conclude with the relevance of the Chemistry Career.

These results were complemented with the application of questionnaires on the challenges for the pertinent and adequate training for the needs of the employer sector. The questionnaire was structured according to the study variables: industrial sector in relation to the objectives of sustainable development and the role of the chemical professional, these variables were derived in dimensions and their corresponding indicators that guided the content of the data collection instrument. Once structured, the questionnaire was validated by the judgment of three experts who reviewed and observed the correspondence of the data collection instrument with the research objective, variables and dimensions, as well as the appropriate use of language and response scale.

Subsequently, focus groups were held, in which criteria were obtained from the representatives of the national industry on the current and expected role of the chemical professional. These elements allowed the situational analysis or diagnosis regarding the potential participation of the chemical professional in terms of the tensions or social requirements determined in the current regulations and proposals made by the business sector linked to the work environment of the chemist.

1.2 Sample

The sample was made up of representatives of the national industry linked to the field of chemistry. The sampling was non-probabilistic and intentional, since it was aimed at people linked to the chemical industry, who could provide the best criteria on the sector's requirements and who gave their informed consent to participate. In the first instance, in order to apply a questionnaire through the Microsoft Forms platform, representatives of the industrial sector of the areas related to chemistry in the city of Quito were called by e-mail and direct message, with the collaboration of the Quito Chamber of Commerce and the Association of Chemists of Ecuador. Subsequently, in order to deepen the responses provided, with a qualitative analysis, the 51 respondents were invited by e-mail and direct message to participate in a focus group, of which 17 people agreed to contribute anonymously.

1.2 Data processing

To establish the content of the questionnaire, the study variables were operationalized according to the instructions in Table 1.

Variable	Dimensiones	Indicators
Industrial sector vis-à-vis relevant sustainable development objectives	Challenges	Degree of implementation of cleaner production processes in the company.
	Alliances with universities	Degree of interest in receiving training from universities.
	Skills of the chemical professional	Level of skills demanded by the industrial sector

Table 1. Operationalization matrix for variables

The responses to the questionnaire were tabulated, organized, filtered and presented with graphs to obtain orderly and comprehensible information. The statistical treatment of the results was approached through the use of descriptive statistical tools (bar and pie charts). Relative frequencies corresponding to the response options of the questions that formed part of the questionnaires were established. In addition, a series of filters were established to set contexts in obtaining more specific frequencies and graphs for a given variable (questionnaire question).

The graphs were obtained with the help of Power BI Desktop software which is a free application from Microsoft and aims to centralize large volumes of data to produce impact graphs to aid decision-making. Regarding the qualitative analysis, the focus group was conducted on two different dates, in 2023, through the Zoom platform, where groups were generated depending on the area in which the participants worked; food and beverages for human consumption, food and supplies for animal consumption, construction and/or metallurgy, plastics, leather and textiles, agrochemicals and environmental. The groups were led by professionals related to each area. Subsequently, open questions were asked, validated by experts, related to the field and spheres of action of the chemical professional.

The focus group questions were derived from the categorization matrix, which served as a basis for the semi-structured interview with the following categories:

- Interest in receiving training from the Universidad Central del Ecuador
- Interest in solving problems presented by companies
- Cleaner production alternatives in the workplace.

The results obtained were transcribed and analyzed to determine points of agreement and disagreement, which allowed for a more holistic analysis of the importance of the role of the chemist in the industrial scenario.

2. Results and discussions

The results are presented on the basis of three methodological procedures followed:

1. Bibliographic review of regulations and legal basis to establish the relevance of the professional in terms of these regulations and legal basis.
2. Results of the questionnaire.
3. Results of focus groups.

1.2 Contributions of the chemical professional in the national, regional and current world scenario.

Table 2 shows the contribution of chemical professionals in three important productive sectors in Latin America and the Caribbean, for example, with their scientific knowledge in instrumental chemistry the quality of the soil is determined, promoting productivity in the agricultural and livestock sector, therefore, chemical professionals can contribute to SDG 1 (End Poverty), SDG 2 (Zero Hunger). "More than 700 million people in the world live in extreme poverty, where its main causes are: unemployment, social exclusion and the high vulnerability of some populations to disasters, diseases and other phenomena that prevent them from being productive" (UN, 2023, para. 10). Chemical professionals contribute to poverty eradication (SDG 1), because, through their scientific knowledge, they enable industrial development (SDG 9) leading to economic growth and employment generation (SDG 8).

To illustrate the above, Table 2 highlights the importance of chemical parameters to determine the quality of manufactured products such as flour. The manufacturing sector has a higher percentage of annual growth rate (8.6) with respect to other productive sectors, this is mainly due to innovation and development of new products (SDG 9), where chemical professionals can contribute with their knowledge. In addition, strengthening industrial development generates economic growth (SDG 8), which results in job creation and poverty reduction (SDG 1).

Production sector	Millions of dollars	Annual growth rate (Percentage))	Role of the professional chemist
Agriculture, livestock, hunting, forestry, and fishing	259 972.2	1.5	AGRICULTURE: NTE INEN-ISO 10382 indicates that soil quality is determined through the quantification of organochlorine pesticides and polychloride biphenols by gas chromatography with electronic capture detection (INEN, 20114).
Mining and quarrying	190 449.0	4.4	The essential chemical element for battery production is lithium, where Latin America accounts for 52% of world reserves, located in Chile (41%) and Argentina (10%) (ECLAC, 2023b)..
Manufacturing industries	678 046.5	8.6	The Codex Alimentarius states that edible cassava flours must comply with several quality parameters such as: crude fiber (max. 2.0%), ash (max. 3.0%), food additives and certain particle size if it is considered fine or coarse flour (CODEX ALIMENTARIUS, 2019).

Table 2 Role of the chemical professional in the different productive sectors in Latin America (UN, 2022)

On the other hand, lithium has been considered an important resource in Latin America, however, its extraction requires abundant water; therefore, chemical professionals can contribute with scientific knowledge to develop research focused on a circular economy in the mining sector, as ECLAC has already done in its expert workshop "From traditional mining to sustainable mining: a comprehensive approach" (ECLAC, 2023a). In this context, the National Survey of Employment, Unemployment and Underemployment (ENEMDU) reports that in April 2023 there was 4.0% unemployment in Ecuador (INEN, 2023). In this aspect, the chemistry career would have a significant contribution because the objectives and contents of the subjects seek to train professionals with knowledge to implement new businesses in the chemical area, which results in increasing and promoting employment.

A similar alternative is mentioned in objective 5 of the economic axis of the Development Plan for the New Ecuador 2024-2025, which consists of promoting production in a sustainable manner, improving productivity levels to reduce unemployment and improve the quality of life of Ecuadorians (SENPLADES, 2024).

Considering the local level; according to results from the Central Bank of Ecuador, poverty in the province of Pichincha for 2019 was 13% (Pichincha, 2019). Table 3 shows the role of chemical professionals in the development of different economic activities that contribute to the sustainable development objectives: food, metallurgy, chemical products, plastics, textiles and leather.

Economic activity	**Thousands of dollars**	**Role of the chemist**
Meat processing and preservation	754.085	To preserve the health of consumers, meat products should not contain residues of pesticides or their metabolites and residues of veterinary drugs; for example, the maximum limit of benzylpenicillin in beef is 50ug/Kg (CODEX ALIMENTARIUS, 2021a). For the quantification of these residues, instrumental methods are required that can be carried out by chemical professionals. In addition, chemical professionals can conduct research for the development of new methods that are economical and environmentally friendly, e.g., biosensors (Prado et al., 2015).
Processing of vegetable and animal oils and fats	452.762	The Codex Alimentarius establishes maximum limits for iron and copper in different types of oils, using the atomic absorption method in a graphite furnace (CODEX ALIMENTARIUS, 2021b). This method can only be performed by professional chemists.
Dairy product processing	583.883	The NTE INEN-ISO 1740:2013 standard details the procedure for determining the acidity of milk fat and its derivatives through titration with tetra-n-butylammonium hydroxide (INEN, 2013c).
Processing of milling, bakery	906.885	The NTE INEN-ISO 20483:2013 standard indicates the Kjeldahl procedure to determine the nitrogen and crude protein content in cereals and legumes. The

and noodle products		development of these procedures requires professionals with extensive knowledge in analytical chemistry and industrial safety. (INEN, 2013b)
Sugar processing	4.616	The Codex Alimentarius has determined several physicochemical parameters to determine the quality of sugar; for example, conductivity, inversion by polarized light, pH, color. In addition to parameters involving starch quantification (CODEX ALIMENTARIUS, 2022).
Cocoa, chocolate and confectionery processing	653.985	Codex Alimentarius determines the analytical methods for the quantification of cocoa butter, fat-free dry extract of cocoa and milk (CODEX ALIMENTARIUS, 2016).
Processing of other food products	554.304	The Codex Alimentarius indicates that the nutritional value of a food must be reported on the label, the amount of energy, protein, carbohydrates, fat, specific nutrients per 100 grams of food; the result is obtained through bromatological tests (CODEX ALIMENTARIUS, 2009).
Manufacture of beverages and tobacco products	666.559	NTE INEN 1081:1984, indicates that the quantification of caffeine in carbonated beverages is done through the spectrophotometric method (INEN, 2013a).
Manufacture of textile products, garments; manufacture of leather and leather articles	897.620	The NTE INEN-ISO 17234-1 Standard prohibits the use of certain azo dyes that form toxic amines upon degradation (INEN, 2014d). Therefore, in order to protect human and environmental life, professional chemists are required.
Manufacture of paper and paper products	287.445	NTE INEN-ISO 11480, indicates that the determination of total chlorine and chlorine bound to organic compounds in paper or cardboard, is performed through microcoulombimetry (INEN, 2014g).
Manufacture of chemical substances and products	917.120	Article 51 of the Regulations for the Control and Administration of Scheduled Substances Subject to Control establishes that "aqueous dilutions of acids, bases and oxidants, in concentrations less than or equal to 6 Normal (6N) shall be described on the labels of the containers and shall not be controlled" (REGISTRO OFICIAL, 2020).
Manufacture of rubber and plastic products	490.121	The NTE INEN-ISO 1269 Standard indicates that volatile matter (including water) in plastic materials, resins and homopolymers, are determined by gravimetry (INEN, 2014f).
Manufacture of other non-metallic mineral products	231.962	NTE INEN-ISO 10545-15, indicates that the determination of lead and cadmium emission in glazed ceramic tiles, is performed by atomic absorption spectrophotometry (INEN, 2014a).

Manufacture of base metals and metal products	1.238.246	The NTE INEN 2 492:2009 Standard indicates that high-strength steel sheets are achieved through microalloys with elements such as niobium, titanium and molybdenum (INEN, 2009). The NTE INEN-ISO 15096 Standard establishes that the method for the quantification of silver in jewelry is inductively coupled plasma optical emission spectroscopy (INEN, 2014e).
Mining and quarrying	133.718	The second provision of the Environmental Regulations for mining activities establishes that "The physicochemical, heavy metal, bacteriological and biological laboratory analyses required to comply with the provisions of these regulations, both in environmental impact studies and in environmental monitoring, control and follow-up work, shall be carried out only by laboratories accredited by the Ecuadorian Accreditation Body (OAE)" (REGISTRO OFICIAL, 2011).

Table 3. Role of the professional chemist in the different productive sectors of the Province of Pichincha (BCE, 2020)

8.9% of the world's population suffers from hunger (690 million people) due to human-caused conflicts, climate change and economic downturns, for which the following has been set as a target:

> By 2030, end hunger and ensure access by all people, in particular the poor and those in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round (ONU, 2023, para. 1).

For the development of all types of foods, especially nutritious foods, a multidisciplinary group of professionals is required; in which chemical professionals determine the quality of foods through the quantification of different chemical parameters established by the Codex Alimentarius standards; in addition, chemical professionals have the knowledge to innovate and develop functional foods (SDG 9). According to Bhattarai, food adulteration consists of the elimination of nutrients from food, addition of hazardous substances and contamination with microbial agents; which diminish the quality of the food, causing different diseases in consumers. Therefore, for the development of SDG 2 (Zero Hunger) it is necessary to develop analytical techniques to detect food hazards (Bhattarai et al., 2022).

The United Nations indicates that 13% of food is lost in harvesting, transportation, storage and processing. Therefore, it is necessary to innovate in new technologies (SDG 9) to avoid food waste, such as, for example, ultrasound drying that increases the shelf life of fruits and thus can reach distant places avoiding product loss; in addition, fruit drying facilitates and lowers transportation costs by having a lower weight compared to fresh fruit (Fernandes and Rodrigues, 2023). Chemical professionals have high capacities to develop research in the search for new technologies in food drying.

On the other hand, agricultural production worldwide exceeds 3 billion tons, requiring 187 million tons of fertilizers. However, more than 50% of NPK (nitrogen, phosphorus, potassium) is lost through leaching, photodegradation, chemical hydrolysis and microbial degradation, generating economic and environmental problems. Therefore, it is necessary to seek new technologies (SDG 9) that favor the absorption of nutrients such as nanofertilizers, which have shown an increase in agricultural production of 30% compared to conventional fertilizers (Rahman et al., 2021). For the development of this modern agriculture such as the use of nanofertilizers, chemical professionals with the knowledge and skills to study and manipulate matter on an atomic scale are required. Hence: "Industry in general plays an important role in the development of the world economy. On the other hand, it is the largest consumer of natural resources and one of the largest global polluters. (Montes-Valencia, 2015, p.75).

ECLAC indicates that the war between Russia and Ukraine has increased the price of fertilizers and has made it difficult to import them to Latin America and the Caribbean, since Russia is the world's largest exporter of nitrogen fertilizers, the second largest supplier of potassium and the third largest exporter of phosphate fertilizers (ECLAC, 2022). Therefore, there is a need for chemical professionals with the capacity to increase regional production and the development of new technologies such as nanofertilizers.

Considering SDG 3 (Health and well-being) the National Agency for Regulation, Control and Sanitary Surveillance establishes as the seventh requirement for obtaining the sanitary registration of medicines: Description of analytical methods for the quantification of active ingredients (ARCSA, 2022); an activity that specifically requires chemical professionals with knowledge in the validation of analytical methods to ensure the quality of pharmaceutical products.

Similarly, chemical professionals, having knowledge of organic and inorganic molecule synthesis, development of new bulk materials and nanotechnologies, can contribute significantly to the research and development of innovative pharmaceutical products (ARCSA, 2022).

3.2 Contributions of the professional chemist in the environmental sector

The "chemical professional has a relevant degree of influence for the detection and quantification of pollutants in the various ecosystems, access to clean water and the development of new materials to ensure affordable and non-polluting energy" (Martínez et al., 2023, p. 21). With respect to SDG 13 (Climate Action), the current Development Plan for the New Ecuador 2024-2025 proposes to promote circular models that contribute to the reduction of pollution of natural and water resources (SENPLADES, 2024). The implementation of these sustainable models would be possible with chemical professionals who have the knowledge to transform matter, i.e., from waste, generate innovative products for reuse. To this end, the educational approach should not be limited to the transmission of technical knowledge on sustainability and chemistry, but should also foster critical awareness in professionals, so that they question and transform existing structures that perpetuate exploitation and environmental degradation.

Similarly, in order to contribute to waste reduction, chemical professionals are able to implement projects that replace toxic and hazardous substances with environmentally friendly substances, through the discipline known as green chemistry (Raj et al., 2022). These professionals must have the capacity to innovate in the reuse of waste and the creation of products that promote a circular economy, thus contributing to a structural change in the relationship between society and nature.

The data reported in Technical Bulletin No 04-2020-Municipal ADGs, on Drinking Water and Sanitation Management, is related to SDG 6 (Clean Water and Sanitation); in which it is reported that 90% of municipalities have one or more water treatment systems and 83.3% of municipalities declare compliance with INEN Standard 1108 that determines water quality (INEC, 2021). Therefore, to complete the deficit of municipalities without access to water in Ecuador, there is a need for professional chemists who know the processes of potabilization and determination of water quality, through analytical methods reported in the aforementioned regulations.

In this sense, as shown in Table 4, the professional chemist has an important responsibility, due to the physicochemical analysis of parameters such as ions, heavy metals, total soluble solids, chemical oxygen demand, as parameters of drinking water quality, as well as the detection of traditional contaminants such as heavy metals and emerging ones such as plastics and antibiotics.

Regarding SDG 7 (Affordable and clean energy), SDG 14 (Underwater life) and SDG 15 (Life of terrestrial ecosystems), the state of diverse and deep contamination in all ecosystems of the planet requires emerging attention of specialized professionals, who investigate various pollutants, generate proposals for change and positively influence public policies that seek to mitigate global warming and the pollution and destruction of ecosystems. The chemical professional has the necessary training and knowledge to develop specific research projects, such as pollutant detection and generation of new materials to collaborate in the evaluation of ecosystem pollution and generate biodegradable and non-polluting materials. Table 4 describes several examples that relate the chemical professional to the various Sustainable Development Goals.

Sustainable Development Goals	Role of the professional chemist
CLEAN WATER AND SANITATION	The NTE INEN-ISO 10304-3 Standard indicates that the determination of anions (iodide, thiocyanate, thiosulfate, sulfite and chromate) dissolved in water are determined by liquid phase ion chromatography (INEN, 2014b).
AFFORDABLE AND NON-POLLUTING ENERGY	Biofuels are a renewable energy source that can replace petroleum. For example, biofuel obtained from microalgae has been used for air transportation, showing several advantages compared to alkanes (Jayakumar et al., 2023)
CLIMATE ACTION	Raw material production from CO_2 photocatalysis as a reduction strategy to reduce greenhouse gas emissions (Guo et al., 2023).)
UNDERWATER LIFE	The NTE Standard indicates that the determination of ions (Li^+, Na^+, NH_4^+, K^+, Mn^{2+}, Ca^{2+}, Mg^{2+}, Sr^{2+} and Ba^{2+} in wastewater is determined by ion chromatography (INEN, 2014c)
LIFE OF TERRESTRIAL ECOSYSTEMS	The development of alternative materials to wood, such as composites from waste such as expanded polystyrene, rice husk, sawdust, which have better physical-mechanical properties compared to commercial composites (Bollakayala et al., 2023).

Table 4. Sustainable Development Goals associated with the role of the chemical professional. Own elaboration.

3.3 New challenges for the Ecuadorian industry in chemical processes, facing the relevant SDGs

In this section, the results of the survey and the focus group were analyzed simultaneously, since the findings found quantitatively in the survey of the 51 chemical professionals were analyzed in greater depth qualitatively with the 17 participants of the focus group.

For the focus group, the participants were subdivided according to their area of expertise, which was beneficial in facilitating understanding among the members of each group by using a common language when communicating. However, the results did not differ, which is why a joint analysis of the data collected was made.

In the survey conducted, the challenges of the industry regarding cleaner production in the companies where the respondents work became evident. Where, waste recycling with 30.43% followed by efficient production methods with 19.13% are the most implemented processes (Figure 1). Results that seem to respond to the legislation established in the country but not necessarily to a genuine interest in seeking a greener industry, added to the lack of knowledge on how to approach or implement a less polluting production according to the considerations analyzed with the participants of the focus group, a fact that has been expressed in other investigations that reflect the limitations of the Ecuadorian industry (Anchatipán Bastidas and Flores Tapia, 2023). Therefore, the teaching of chemistry should be directed to promote skills tending to the "study of substances and their transformations should contribute to the formation of the scientific conception of the world by revealing causal relationships and interdependence"(Caballero, 2017, p.5).

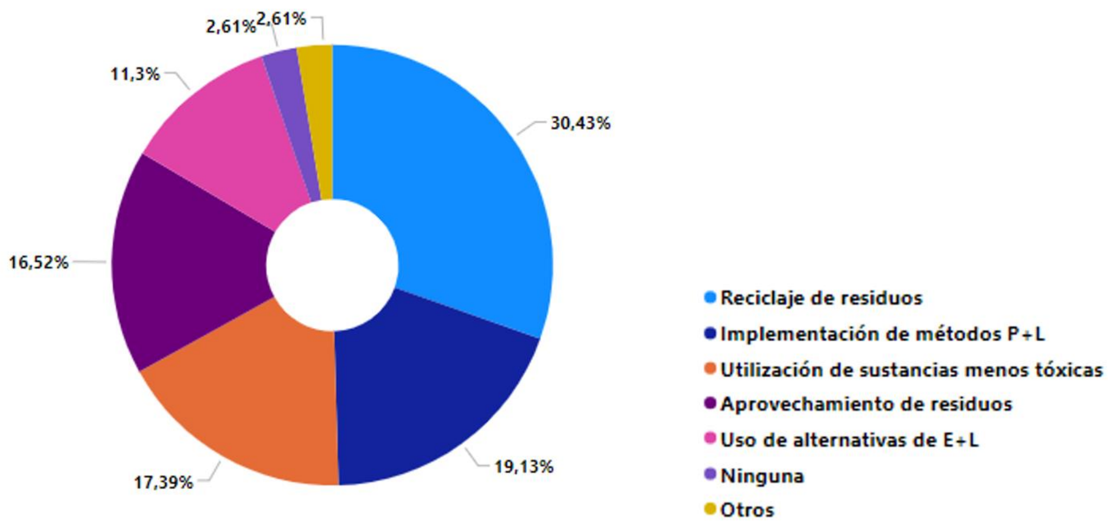

Figure 1. Selection of cleaner production processes applied in the surveyed companies

Note: CP, cleaner production; CP, cleaner energy.

Source: own elaboration

In addition, as shown in Figure 2, the survey provided useful information on the level of interest of chemical professionals and the companies they represent in addressing problems related to the following issues:

- Production: optimization, formulation, innovation, among others.
- Waste management.
- Quality of finished products: analysis, shelf life, among others.
- Raw materials: conservation, high costs, shortages, among others.

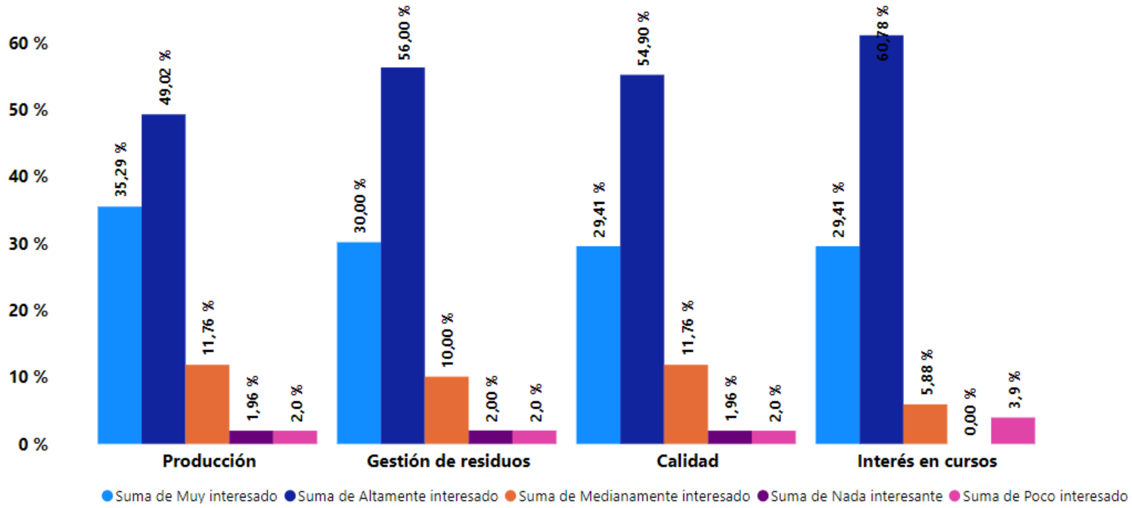

Figure 2. Level of interest of chemical professionals and the companies they represent

Figure 2 shows that there is a high level of interest in employing corrective actions in response to the problems presented, exceeding 40% in all the established parameters. However, economy plays a significant role in all these procedures, as highlighted in the focus group. This criterion goes hand in hand with 60.78 % of the respondents, highly interested in receiving training from academia to improve industrial processes (Figure 3). When delving deeper into the topic within the focus group, it was evident the inherent need for training in addition to expressing the importance of a constant rapprochement between industry and academia. Given that academia provides the fundamentals and innovation while industry provides the funding and market knowledge, collaboration between the two is crucial (Guachi, 2019).

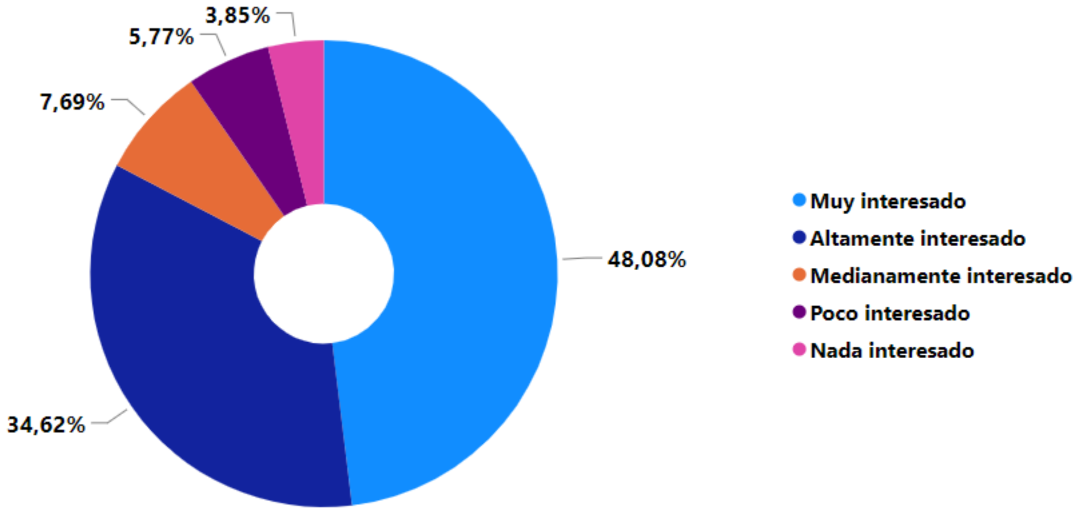

Figure 3. Degree of Interest in University Training Courses to Improve Business Production: A Respondent Perspective

4. Conclusions

The results obtained through focus groups indicate that the implementation of cleaner production practices in companies is insufficient. Most of the participants mentioned that they have focused mainly on efforts related to waste recycling. Regarding collaborations with academic institutions, interviewees noted that interaction with academia is limited in terms of addressing and solving the challenges associated with waste generation in various industrial processes. Therefore, the educational model should be oriented to the early interaction of the student with its sphere of potential performance, in order to achieve a solvent training and development of knowledge and skills, this is feasible through the development of a system of relevant and contextualized pre-professional practices.

In this scenario, the representatives of the companies interviewed expressed a clear interest in establishing closer links with academic institutions. They seek access to knowledge updates, continuous training and advice on processes that are aligned with the competencies that a chemical professional can provide. Regarding the literature review on the Sustainable Development Goals (SDGs) and the relevant regulatory frameworks for the creation of a professional chemist profile in line with the current context, several key elements were identified. The SDGs, as an international framework, the Constitution of the Republic of Ecuador, Development Plan for the New Ecuador 2024-2025 and the Development and Territorial Planning Plan 2019-2023 of the Prefecture of Pichincha, establish the political and normative bases that serve as a starting point for the development of a relevant curriculum for chemical professionals.

In particular, the bibliographic analysis revealed that the opportunities and relevance of chemical professionals are linked to national and international regulations that companies and industries in the country's productive sector must comply with. These regulations include standards such as the INEN regulations and the Codex Alimentarius. Chemical professionals can play a crucial role in the development of technical solutions, as well as in the creation of experimental bases for innovation and development.

These professional competencies, together with their theoretical and technical knowledge, translate into the ability to develop relevant learning content in the current context. In addition, these regulations have been directly linked to the productive sectors of greatest economic influence in the country, such as the manufacture of metals and derived products, the production of chemical substances, the manufacture of textile and leather products, and the elaboration of milling, bakery and noodle products. Therefore, it is essential to take these sectors into account when designing the curriculum for chemical professionals and to promote their positive influence in these economic areas.

The environmental field is currently a highly relevant field of influence for chemical professionals. In a context of widespread pollution of ecosystems and global warming, the participation of chemical professionals offers the opportunity to identify and characterize pollutants of organic and inorganic nature. In addition, they can contribute to innovation in biodegradable materials that help mitigate pollution and contamination problems, as well as generate solutions to counteract climate change.

The pertinent and adequate training of a chemical professional implies the adoption of an educational posture that allows their training in the ethical, scientific, research and society linking fields requires a comprehensive approach that consolidates knowledge, skills and values. It is essential to provide a solid foundation in the chemical sciences, ensuring that students understand the fundamental principles and advanced applications of chemistry. This is achieved through a rigorous curriculum that includes the development of experimental laboratory practices, research projects and the integration of emerging technologies. However, professional education must be accompanied by ethics education that addresses the social and environmental implications of chemical practice. This implies the inclusion of professional ethics courses, where real cases are discussed and the impact of chemical decisions on society and the environment is reflected upon. In addition, it is crucial to foster critical thinking that allows future professionals to question established practices and seek innovative and sustainable solutions. In this way, education not only trains a competent technician, but also a committed citizen, capable of contributing ethically and with critical thinking to the positive transformation of society and the care of the planet.

The interlearning theories adopted for the formation of the chemical professional should guide the practice of participatory and collaborative methodologies with the support of information and communication technologies and, based on the development of problem-based learning, inverted classroom, augmented reality and interdisciplinary projects that link chemistry with various areas of knowledge.

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Statement of Authorship-CRediT

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