

Chemical Industry Waste Treatment in the Last Decade: A Systematic Literature Review (SLR)

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Abstract— Literature studies on industrial waste management have been broadly reported within the last decade. Most studies reported various disciplines, however chemical industry waste treatment studies are limited. This research points to supplying and analyzing a diagram investigating chemical industrial waste treatment from 2013 to 2023. This report is vital in supporting progress in economical chemical mechanical waste treatment in the future, through the interpretation of various studies from the Taylor & Francis Online database. This report utilized a Systematic Literature Review (SLR) with a PRISMA flowchart which presented inclusion activity and data search results. Of the 613 articles with 12 sub-fields, 135 articles were selected and then analyzed to obtain 33 articles. As a result, 22 articles met the inclusion criteria and were preferred for this report. It resulted that the research articles on chemical industrial waste treatment were significantly reported although for a few time, there are no articles published. The most cited journal article was published in 2013 with a total citation of 77. Those most cited articles provide information that the most popular research method is green synthesis which has a positive outcome. In the years ahead, various aspects and article types need to be analyzed as well as take a longer period to research published articles.

Keywords— *SLR; Chemical Industrial; Waste Treatment*

I. INTRODUCTION

In addition to the hazards associated with the outcomes of industrial operations, the chemical sector is one of those that has a significant risk of workplace accidents that might result in serious injuries or even death [1]. Extreme circumstances

(high temperature, high pressure, and enormous volume) and the usage of chemicals with dangerous qualities (flammability, explosiveness, and toxicity) are the causes of this high risk [2]. Because of this, occupational health and safety in the chemical sector are crucial for all parties involved, including workers, the local community, and society at large [3]. Training to increase the competency of human resources in the chemical industry is necessary since human factors like work safety culture, awareness, and emergency readiness are typically linked to the primary causes of accidents in the sector [4]. As a result, the chemical industry requires competent individuals who can acquire skills in line with industry demands, particularly in sustainable industry.

Because the chemical industry contributes significantly to the use of energy and raw materials derived from fossil fuels, it necessitates modifications to environmental conservation initiatives, which is why sustainability programs are necessary in this sector [5]. The production process and the environmental effects that follow, including industrial waste, have a very strong tie with the chemical industry. Numerous wastes are often produced by chemical industrial operations, which might be squandered every minute and are impacted by several factors, including Both external and internal factors—such as weather variations, standards and regulations, geological conditions, industry types, industrial practices, and on-site technology—have an impact on the kind and amount of waste produced by industrial processes [6].

This is a serious issue as industrial waste can contain toxins, particulates, and other substances that are bad for the environment, animals, and people [7]. Inadequate waste management techniques, direct waste release into the environment, ignorance, issues with industrial design, and a lack of funding for waste management can all contribute to

this [8]. In waste management strategies that are now being evaluated to promote sustainable industries, these aspects might be highlighted as both restrictions and problems. Consequently, data on various research on waste management or standard treatment is required, particularly in the context of the chemical sector.

Studies on the management or treatment of industrial waste have been discovered and dispersed among some fields, but there are currently few that focus on the waste treatment of the chemical industry. Based on previous research of 46 publications published between 2000 and 2023 on trash treatment for environmental and economic sustainability reveals that waste treatment practices enable sustainable resource management, including reducing energy use [9]. To create a sustainable industry, previous research on a review of 78 scientific publications on waste management and the circular economy from 2012 to 2022 demonstrates how these practices can support the development of environmental ecosystems to meet the UN 2030 agenda's sustainable development goals [10].

Therefore, the goal of this research is to perform a literature review that can offer and evaluate a variety of studies on the treatment of chemical industrial waste during the past ten years. By interpreting different study references across time, this is done to promote the development of chemical industrial waste treatment in a sustainable future.

Numerous papers are thought to be pertinent to this investigation, such as the 2023 Systematic Literature Review (SLR) on Reverse Logistics (RL) e-waste management by Ni, Zhiqin et al., which included analysis, an overview, and a research agenda for the future. According to the findings of this study, six primary research criteria on e-waste RL can be found from 162 English-language journal articles published between 1998 and 2021 that were retrieved from Scopus data sources, specifically 1) e-waste laws and policies, 2) barriers, critical success factors, and solutions, 3) RL e-waste network design decisions, 4) RL e-waste system evaluation and framework, 5) consumer e-waste return behavior, and 6) technology-based RL e-waste innovations. Based on these six research criteria, a conceptual framework for RL e-waste management is constructed, and it has also been able to discuss the limitations and research gaps of each criterion. The proposal of a more thorough future research agenda, including the creation of 13 research criteria, concludes [11].

Furthermore, according to Chen, Xiaowei, et al.'s 2023 Systematic Literature Review (SLR) on sustainable supply chain management in the leather industry, which involved analyzing 61 journal articles published between 1992 and 2022 using data from Web of Science and Scopus, five criteria were found: criteria for the practices, drivers, obstacles, supporters, and outcomes of sustainable supply chain governance in the leather industry environment [12]. Furthermore, this study creates a conceptual framework that allows for the integration of each criterion and generates recommendations and management consequences for the future.

Three liquid waste focus areas—sources and composition of construction liquid waste; construction liquid waste control methods; and construction liquid waste management—were identified from the results of the analysis of 49 journal articles published between 1992 and 2022 in a study by Karunasena, Gayani et al. in 2023 regarding Systematic Literature Review (SLR) on liquid waste management in the construction sector using the PRISMA method (preferred reporting items for systematic reviews and meta-analysis), Bibliometric tools, and VOSviewer [13]. Although the study found a lack of integration between effluent management research and research on water pollution at construction sites, it was still able to highlight the current state of construction effluent management research and identify the need for future studies into the implementation of efficient and effective effluent management practices in construction projects.

Last but not least, according to research done in 2022 by Vieira, Octavia et al. on the Systematic Literature Review (SLR) on the conversion of plastic waste into valuable Graphene-2D-based materials, out of the 142 journal articles on the Scopus data source that are included in research on Graphene-2D-based materials, only 12 articles (9.2%) were examined overall. It was then determined that the synthesis of a monolayer, multiple layers, and multi-layers (including flash graphene) was accomplished using four distinct synthesis methodologies: (i) plastic breaking down thermally right on top of a metal surface; (ii) thermal breakdown of plastic first, followed by ball milling and microwave sintering; (iii) thermal breakdown followed by the release of hydrocarbon gas, which is then fed into a Chemical Vapour Deposition (CVD) system with a metal substrate; and (iv) Flash Joule Heating (FJH) [14].

This research is relevant to the field of study and the methodology employed in the literature study, specifically the study of waste treatment through literature studies using the Systematic Literature Review (SLR) with the PRISMA method (preferred reporting items for systematic reviews and meta-analysis), according to the findings of several studies mentioned above. This study differs from earlier research in that no literature reviews on waste management in the chemical sector have been conducted in the past ten years. The analytic methods and inclusion criteria employed in this study also varied from one another. The research conducted on the treatment of chemical industrial waste throughout the past ten years, from 2013 to 2023, will be examined and summarized in this paper.

II. METHOD

A. Research Design

The purpose of this research's Systematic Literature Review (SLR) is to find, categorize, and explain study findings by the inclusion criteria [15]. Additionally, the PRISMA (preferred reporting items for systematic reviews and meta-analyses) flow chart, which may display the inclusion and exclusion activities of the data search results, was employed in this study's selection method [16]. The distribution of journal articles published annually, The distribution of journal article citations

annually, and Research methodologies and findings are among the factors under analysis. These variables are categorized to see the trend of waste management in the chemical industry in the last 10 years.

B. Inclusion Criteria

The Taylor & Francis Online database was used for the search, and several inclusion criteria were set, including the requirement that research journal articles published within the last ten years, from January 2013 to July 2023, contain the search term "Chemical Industrial Waste Treatment" in the title, abstract, or keywords. The journal article section in the Engineering & Technology sector, with the Chemical Engineering subfield and the Industrial Chemistry topic, was then the only one chosen. Furthermore, only English-language, open-access journal papers were chosen. The analysis did not include conference proceedings, books or portions of books, or preview pieces.

C. Data Analysis

"Chemical Industrial Waste Treatment" was the search keyword used to find relevant journal articles. To make sure the papers were pertinent to the study's goals, the researcher personally determined each article's title, abstract, and keywords. Only articles from the Engineering & Technology sector, namely the Chemical Engineering subfield and the Industrial Chemistry topic, were used as examples for this study. There were 613 items in 12 subfields based on the original search. After choosing one of the subfields, Chemical Engineering, the researcher was able to narrow down the results to 135 journal articles covering 14 different topics. To analyze the waste treatment in the chemical industry during the past ten years, the author selected the more specialized topic of industrial chemistry. The author then examined and double-checked all the papers to make sure the target journal articles fulfilled the requirements and that there were no duplicates after obtaining 33 journal articles. The abstracts and complete texts were reviewed before the final papers were chosen for review. Eleven articles were eventually removed after sorting through the data since they did not relate to the subject under analysis.

Every article was reviewed in full text as part of the selection process. The relevance of the manuscript to the main research issue of whether the article satisfied the inclusion criteria had to be reviewed to provide an accurate and thorough systematic review. An independent assessment was carried out if there was any uncertainty regarding whether the material satisfied the requirements for inclusion. 22 articles in all were chosen for examination after meeting the inclusion criteria. The following Prism diagram illustrates the article selection process's flow.

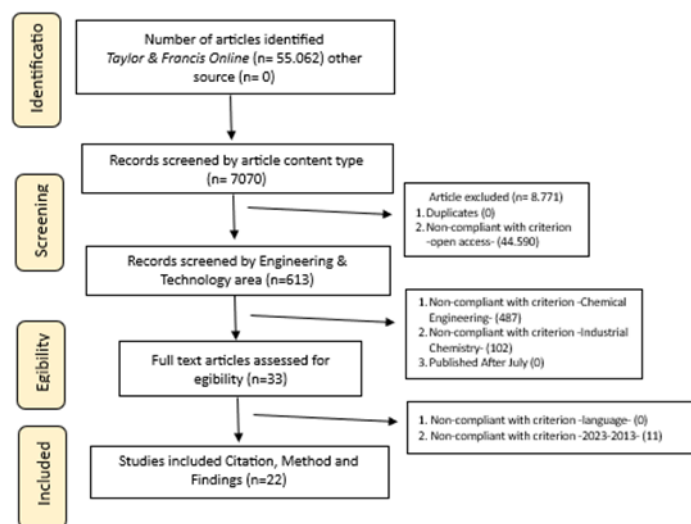


FIGURE I. Journal Article Selection Flow

III. RESULTS AND DISCUSSION

Three sections present the findings of the Systematic Literature Review (SLR) analysis of journal articles published in the Taylor & Francis Online database between 2013 and 2023: the distribution of journal article publications annually, the distribution of journal article citations annually, and the research methods and findings pertaining to chemical or industrial waste treatment.

a. Distribution of Journal Article Publication per Year

Figure 2 below displays the first variable in our analysis, which is the distribution of journal article articles on chemical or industrial waste treatment from January 2013 to July 2023.

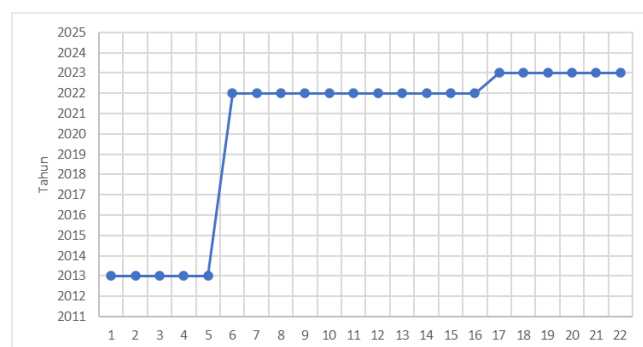


FIGURE II. Distribution Of Journal Article Publications Per Year

The number of publications has increased during the last ten years, from January 2013 to July 2023, according to the findings of the annual publication distribution analysis. With 11 journal papers, 2022 had the most publications on chemical industrial waste treatment. 2023 had the second-highest number with 6, while 2013 had the fewest with 5. Nevertheless, there were no journal articles published between 2014 and 2021. The Green Chemistry Letters and Reviews publication was the source of every article acquired during the previous ten years. This explains why there aren't many journal papers on industrial waste treatment. It may be because of the way the

articles were chosen or because they were chosen based on the study's inclusion criteria.

Researchers and practitioners can better grasp the future directions of Chemical Industrial Waste Treatment research thanks to this study's effective presentation of a thorough review of earlier literature studies. Despite a temporal lag that indicates no papers were published between 2014 and 2021, the analysis's findings make it evident that the number of publications has significantly increased over the last ten years. The results of a literature review on waste treatment using life cycle assessment of active alkaline materials on 246 journal articles in Scopus data sources from 2000 to 2022, which revealed a sharp rise in the number of article publications from year to year, are consistent with this finding regarding the increase in publications [17]. Because it is thought to be able to give the most recent references pertaining to safe and sustainable industrial waste treatment systems, waste management has emerged as a research trend, particularly in the chemical sector. Additionally, this trend in the advancement of industrial waste treatment research is in line with the United Nations Environment Program's recommendations to avoid, reduce, reuse, recycle, recover, treat, and dispose of waste in order to minimize the amount of waste that ends up in landfills [18]. As a result, it is anticipated that the number of publications on waste treatment, particularly in the chemical sector, would rise sharply annually.

b. Distribution of Journal Article Citation Counts by Year

The 22 journal articles that were examined yielded the third variable of the distribution of journal article citations annually; the findings are shown in Figure 3 below

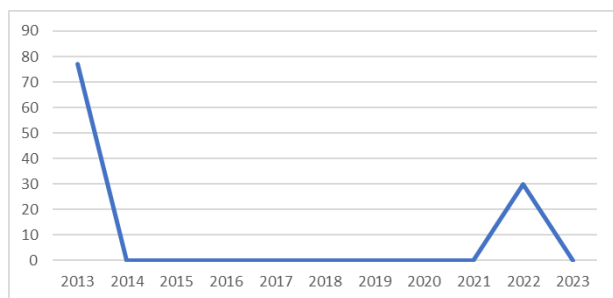


FIGURE 3. Distribution Of Journal Article Citations Per Year

According to the findings of the analysis of the distribution of journal article citations annually for the last ten years, from 2013 to 2023, in the journal *Green Chemistry Letters and Reviews*, the year 2013 had the most citations, totaling 77, distributed among five journal articles, each of which received 25 citations, 19 citations, 19 citations, 7 citations, and 7 citations. With a total of 30 citations distributed over seven journal articles, the next-highest number of citations occurred in 2022, with each publication receiving 15 citations, 6 citations, 3 citations, 2 citations, 1 citation, and 1 citation.

The research findings of Yanga, Jinming, et al. (2013) about clean procedures for the synthesis of 1,4-

dihydropyridines through the Hantzsch reaction in water, with a total of 25 citations, ranked first among the seven journal articles that were sorted according to the five rankings of the highest number of citations. The next rank had 19 citations in 2 journal articles in 2013, including one by Aerrya, Swati et al. on chemoselective acetylation of amines and thiols using dispersed Ni nanoparticles and another by Abdul, Ebtesam et al. on green methodology in organic synthesis; recent developments in the laboratory.

The journal article by Yina, Xi-Tao et al. in 2022 about high-performance Sr-doped active porous LaFeO_3 semiconductors made using the sol-gel process had the next-highest number of citations, which came to 15. The next highest number of citations, seven, were found in two separate articles published in 2013. One of these articles was by Chaskara, Atul et al. and discussed the practical and effective synthesis of 1-aryl-1H,3H-thiazolo[3,4-a]benzimidazole using sodium hydrogen sulfate and silica as a heterogeneous catalyst, while the other was by Sriniyasa B. et al. and described the green and effective PEG-600-mediated tandem synthesis of N-substituted-2-styrylquinazolin-4-1. The journal article by Abdel, Reda, et al. in 2022 about the green synthesis of heterocyclic polyol systems of zinc sulfide-organic nanoparticles as environmentally friendly anti-corrosion and anti-bacterial corrosion inhibitors for steel in acidic environments had the most citations (6), ranking fifth.

Future researchers may be able to produce more thorough and comprehensive research throughout the year, as the variation in the number of journal article citations per year raises concerns about the continued lack of authors interested in discussing waste treatment and conducting additional research, particularly in the chemical industry.

c. Research Methods and Findings

The fourth component relates to study findings and methodologies. Out of the 33 journal papers that were chosen, 22 were deemed eligible for analysis. A number of publications in the top 5 rankings with the most citations were then chosen to provide further details about the study findings and methodology. Table 1 below displays the information from the 22 journal papers that were examined.

TABLE I

JOURNAL ARTICLE ANALYSIS RESULTS

No.	The Authors	Title	Year	Citation	Author's Country of Origin
1	Jinming Yang, Chenning Jiang, Jiaojiao Yang, Cunwei Qianband Dong Fang[19]	A clean procedure for the synthesis of 1,4-dihydropyridines via Hantzsch reaction in water	2013	25	The People's Republic of China
2	Ebtesam Abdul Aziz Hafeza, Saleh Mohammed Al-Mousawib, Moustafa Sherief Moustafab, Kmal Usef Sadekand Mohamed Hilmy Elneadi[20]	Green methodologies in organic synthesis: recent developments in our laboratories	2013	19	Egypt and Kuwait
3	Swati Aerya, Ajeet Kumara, Amit Saxena, Arnab Deband Subho Mozumdar[21]	Chemoselective acetylation of amines and thiols using monodispersed Ni-nanoparticles	2013	19	India, Columbia, and the United States of America
4	Xi-Tao Yin, Hua Huangb, Jie-Li Xie, Davoud Dastanc, Jing Lid, Ying Liua, Xiao-Ming Tana, Xiao-Chun Gaoa, Wahab Ali Shaheand Xiao-Guang Ma[22]	High-performance visible-light active Sr-doped porous LaFeO ₃ semiconductor prepared via sol-gel method	2022	15	The People's Republic of China and Pakistan
5	Atul Chaskara, Vikas Padalkar, Kiran Phatangareb, Santosh Takalecand Kaliyappan Murugan[23]	An efficient and practical synthesis of 1-aryl-1H,3H-thiazolo[3,4-a]benzimidazole using silica-supported sodium hydrogen sulfate as a heterogeneous catalyst	2013	7	Italy, Republic of China (Taiwan), and India
6	B. Srinivasa Reddy, A. Naidu, and P. K. Dubey[24]	PEG-600-mediated, green, and efficient, tandem syntheses of N-substituted-2-styryl quinazoline-4-ones	2013	7	India
7	Reda Abdel Hameeda,b, Mohamad Faridea,b, Mohamad Othmana,b, Bader Huwaimelb,c, Saedah Al-Mhyawid, Ahmed Shamroukhe, Fereah Alshammariyf, Enas Aljuhanigand Metwally Abdallah[25]	Green synthesis of zinc sulfide nanoparticles-organic heterocyclic polyol system as eco-friendly anti-corrosion and anti-bacterial corrosion inhibitor for steel in acidic environment	2022	6	Saudi Arabia and Egypt
8	Jangam Lakshmidhevia, Bandameeda Ramesh Naidua, Satya Kumar Avulab, Anjoy Majhic, Poh Wai Chiad,e, Ahmed Al-Harraisband Katta Venkateswarlu[26]	A waste valorization strategy for the synthesis of phenols from(hetero)aryl boronic acids using pomegranate peel ash extract	2022	3	India, Oman, and Malaysia
9	Ashleigh Naysmitha, Naeem S. Mianband Sohail Rana[27]	Development of conductive textile fabric using Plackett-Burman optimized green synthesized silver nanoparticles and in situ polymerized polypyrrole	2022	2	The United Kingdom
10	Ludivine Vieira-Sellaia, Mercedes Quintanaa, Ousmane Diopb, Olivier Mercierc, Sebastien Tarrita, Nawal Raimb, Alassan Bab, Benoit Maunizand Marie-Josephe Galmier[28]	Green HPLC quantification method of lamivudine, zidovudine, and nevirapine with identification of related substances in tablets	2022	2	France
11	Amandine L. Flourat, Nour Zeaiter, Erwan Vallée, V. P. Thinh Nguyen, Sami Fadlallahand Florent Allais[29]	A sustainable preparative-scale chemo-enzymatic synthesis of 6-hydroxy-5,7-dimethoxy-2-naphthoic acid (DMNA) from sinapic acid	2022	1	France
12	Zuzana Kudličkováa, Martin Stohrskýb, Radka Michalková, Maria Vilkováand Matej Baláž[30]	Mechanochemical synthesis of indolyl chalcones with antiproliferative activity	2022	1	Slovakia
13	Masudulla Khan, Azmat Ali Khan, Aiman Parveen, Kim Min, Virendra Kumar Yadav, Azhar U. Khan & Mahboob Alam[31]	Mitigating the growth of plant pathogenic bacterium, fungi, and nematodes by using plant-mediated synthesis of copper oxide nanoparticles (CuO NPs)	2023	0	India
14	Márcia G. A. da Cruz, Joy N. Onwumerea, Jianhong Chena, Björn Beeleb, Maksym Yaremec, Serhiy Budnykd, Adam Slabona,band Bruno V. M. Rodrigues [32]	Solvent-free synthesis of photoluminescent carbon nanoparticles from lignin-derived monomers as feedstock	2023	0	Sweden, Germany, Switzerland, and Austria
15	Viswanathan Sukumara, Saravanan Chinnusamy, Hemanth Kumar Chanduluruband Seetharaman Rathinam[33]	Method development and validation of Atorvastatin, Ezetimibe and Fenofibrate using RP-HPLC along with their forced degradation studies and greenness profiling	2023	0	India
16	Naveenarani Dharuman, Karunanidhi Santhana Lakshmi and Manikandan Krishnan[34]	Environmental benign RP-HPLC method for the simultaneous estimation of anti-hypertensive drugs using analytical quality by design	2023	0	India
17	Jessica Pichler, Rosa Maria Edera, Lukas Widdera, Markus Vargaa, Martina Marchetti-Deschmannband Marcella Frauscher[35]	Moving towards green lubrication: tribological behavior and chemical characterization of spent coffee grounds Oi	2023	0	Austria
18	Ibrahim Karumea, Simon Bbumba, Moses Kigozib, Alice Nabatanzi, Is'harq Z. T. Mukasand Solomon Yiga[36]	One-pot removal of pharmaceuticals and toxic heavy metals from water using xerogel-immobilized quartz/banana peels-activated carbon	2023	0	Uganda
19	Cristina Blazquez-Barbadilloa,c, Juan Francisco González, Andrea Porcheddub, David Virieuxc, José Carlos Menéndezand Evelina Colacino[37]	Benign synthesis of therapeutic agents: domino synthesis of unsymmetrical 1,4-diaryl-1,4-dihydropyridines in the ball-mill	2022	0	Spain, Italy, and France
20	Davide Blasia, Davide Mestoa, Pietro Cotugnoa, Cosima D. Calvanoa, Marco Lo Prestiband Gianluca M. Farinola[38]	Revealing the effects of the ball milling pretreatment on the ethanolsolvifractionation of lignin from walnut and pistachio shells	2022	0	Italy and the United States of America
21	Jorge Gomez-Carpintero, Clara Cabrero, Juan Domingo Sánchez, Juan Francisco González and José Carlos Menéndez[39]	A sequential multistep process for the fully mechanochemical, one-pot synthesis of the antiepileptic drug rufinamide	2022	0	Spain
22	Moses O. Alfreda,b,c, Chidinma G. Olorunnisola, Temidayo T. Oyeturdeb, Peter Darea, Raquel R. C. Vilelad, Andrea de Camargod, Nurudeen A. Oladojae, Martins O. Omorogiea,b, Ohumide D. Olukannia,f, Artur de Jesus Motheocand Emmanuel I. Unuabonah[40]	Sunlight-driven photocatalytic mineralization of antibiotic chemical and selected enteric bacteria in water via zinc tungstate-imprinted kaolinite	2022	0	Brazil and Nigeria

Of the 22 journal papers on chemical industry waste treatment published in the Green Chemistry Letters and Reviews journal, the analysis table above indicates that there are five top rankings for the quantity of journal article citations, which are attained by articles 1 through 7. According to journal article number 1, the research method used is the synthesis of 1,4-dihydropyridine through a one-pot Hantzsch reaction in aqueous media without the use of catalysts and/or organic solvents. The research findings are in the form of designing a new, clean, and efficient procedure for the synthesis of 1,4-dihydropyridine through a one-pot Hantzsch reaction with a satisfactory yield of 86-96%. The advantages include avoiding leakage and minimizing emissions, high performance and efficiency that can be recycled, and the potential to apply green synthesis [19].

According to research methods related to the development of environmentally friendly methods for the synthesis of polyfunctional heteroaromatic substances, as shown in Article 2, our new green methodology has been able to produce a large number of polyfunctional aromatic substances in a highly efficient manner, with fewer risks than traditional preparative methods and at a lower cost [20].

As can be seen in article number 3, the research method is the effective use of Ni nanoparticles to catalyze the acetylation of various amines and thiols under environmental conditions at room temperature. The research findings indicate that Ni nanoparticles are an effective catalyst for the acetylation of thiols and aliphatic and aromatic amines, meaning that this method is very quick, can be used instead of costly reagents and high temperatures, and can produce better results [21].

Using the sol-gel method to create Sr-doped porous LaFeO₃ samples, as described in Article 4, the research findings indicate that -OH species are the predominant intermediate oxidants involved in the oxidation of 2,4-DCP and RhB when compared to optimized samples. This research could open up a new avenue for environmental remediation based on LaFeO₃ semiconductors [22].

The research method used in article number 5 involves the use of heterogeneous catalysts and multicomponent reactions to synthesize 1-aryl-1H,3H-thiazolo[3,4-a]benzimidazole derivatives through condensation reactions of aromatic aldehydes, 2-mercaptoacetic acid, and o-phenylenediamine using NaHSO₄×SiO₂ as catalysts. The results of the study show that sodium hydrogen sulfate (NaHSO₄×SiO₂) supported by silica can effectively catalyze the reaction of three components, including aromatic aldehydes, 2-mercaptoacetic acid, and components of o-phenylenediamine, to form 1-aryl-1H, 3H-thiazole, which corresponds to [3,4-a]benzimidazole. This catalyst is unquestionably affordable, eco-friendly, and effective in a variety of conditions [23].

The study methodology, as demonstrated in article number 6, is the green and effective tandem synthesis of N-substituted-2-styrylquinazolinones by polyethylene glycol (PEG)-mediated analysis. This study's conclusions indicate that it has effectively created a mild, effective, and practical tandem synthesis of N-substituted-2-styryl-4(3H)-quinazolinones (5a l) in PEG-600 using two different pathways (1235 or 1245) [24].

The green synthesis, characterization, and assessment of zinc sulfide nanoparticles (ZnS) via chemical precipitation technique is the research methodology employed in article number 7. Here, zinc sulfide nanoparticles were made by the chemical precipitation approach using a sensitizer made of heterocyclic polyvinyl alcohol (PVA). According to the study findings in this journal article, adding PVA and PEG as organic polyol materials enhances the zinc sulfide nanoparticles' adsorption and inhibitory capabilities on the steel surface [25].

Research trends in the processing of chemical industrial waste may be seen from the results of the discussion of different research methodologies and research findings in seven journal articles that are in the top 5 rankings with the most citations. The majority of research techniques use green synthesis, which considers environmental sustainability while utilizing efficient and successful chemical processes. The conformance between the experimental aim and the experimental outcomes may be used to show facts, which makes the entire study findings favorable. Researchers may become more interested in studying the chemical industry in the future as a result, particularly with reference to deeper and more thorough waste processing

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IV. CONCLUSIONS

The following conclusions may be made in light of the features of research publications on the treatment of chemical industrial waste:

- Although there is a time lapse between 2014 and 2021, which indicates that no papers were published, there has been a notable rise in the amount of publications during the previous ten years, from 2013 to 2023.
- In 2013, there were five journal papers with a total of 77 citations, which was the most ever. Each publication had 25 citations, 19 citations, 19 citations, 7 citations, and 7 citations. With 30 citations altogether, distributed among seven journal articles, the next-highest amount of citations occurred in 2022. Each publication received 15 citations, 6 citations, 3 citations, 2 citations, 1 citation, and 1 citation.
- This study's research methodology mostly consists of green synthesis, which utilizes efficient and effective chemical processes while also considering environmental sustainability. Since the existence of conformity between the experimental aim and the experimental results might support the truth, the total research findings provide favorable outcomes.

This study is only sourced from one database, and the period taken is limited to only ten years. In addition, the inclusion criteria used are still limited, so further development is needed. Regarding recommendations for more research, it is hoped that they would talk about additional inclusion criteria so that the literature review yields more thorough findings and serves as a resource for comprehending current research trends.

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