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Synthesis of Iron-based and Aluminum-based Bimetals: A Systematic Review

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ADMINISTRATIVE INFORMATION

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 7 April 2025 and was last updated on 7 April 2025.

INTRODUCTION

Review question / Objective What were the methods employed for synthesizing Fe-based and Al-based bimetals in the last 10 years (2014-2023)?

Condition being studied Bimetals are materials made from two distinct metals with different redox potentials, providing enhanced electronic, optical, and catalytic properties compared to monometallic materials. They have the ability to form galvanic cells, which promote reduction or oxidation reactions depending on their geochemical context. Due to their promise as sustainable catalysts and adsorbents, bimetals are gaining significant attention in circular economy applications. Although several review articles have examined the synthesis methods and applications of bimetallic systems, none have focused comprehensively on Fe- and Al-based bimetals. This systematic review aimed to address this gap by evaluating both traditional and emerging synthesis techniques for Fe-based and Al-based bimetals, in addition to conducting a bibliometric analysis of research trends and activities.

METHODS

Participant or population This systematic review examined both traditional and innovative synthesis methods for Fe-based and Al-based bimetals, complemented by a bibliometric analysis of research trends and developments.

Intervention This systematic review did not evaluate any interventions; instead, it focused on summarizing and analyzing synthesis methods of Fe- and Al-based bimetals.

Comparator This systematic review did not include any comparative interventions, as its primary focus was on the synthesis approaches for Fe- and Al-based bimetals, rather than assessing interventions applied to a defined population.

Study designs to be included This systematic review focused on studies that provided detailed information on the synthesis, preparation, and characterization of iron-based and aluminum-based bimetallic materials. Studies were included if they provided sufficient methodological details on synthesis techniques, whether physical, chemical, or biological. Articles were excluded if they were inaccessible, non-English, review articles, conference papers, book chapters, or not directly related to the synthesis of Fe- or Al-based bimetals.

Eligibility criteria Eligibility assessment of full-text articles was performed based on factors such as inaccessibility, being non-English, classification as reviews, conference proceedings, or book chapters, and lack of relevance to the synthesis of Fe-based and Al-based bimetallic materials.

Information sources This study conducted a systematic review of recent research from 2014 to 2023 using the Scopus, Web of Science (WoS), and Google Scholar databases, adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Main outcome(s) Based on the 122 articles analyzed, Fe-based and Al-based bimetal synthesis methods were classified into three: (i) physical, (ii) chemical, and (iii) biological techniques. Physical methods include mechanical alloying, radiolysis, sonochemical, electrical explosion of metal wires, and magnetic field-assisted laser ablation in liquid (MF-LAL). In comparison, chemical protocols covered reduction, dealloying, supported particle methods, thermogravimetric methods, seed-mediated growth, galvanic replacement, and electrochemical synthesis. Meanwhile, biological techniques utilized plant extracts, chitosan, alginate, and cellulose-based materials as reducing agents and stabilizers during bimetal synthesis.

Additional outcome(s) The bibliometric analysis revealed that research on the synthesis of Fe-based and Al-based bimetals initially declined but saw an increase in 2018, followed by a stable trend, with 50% of the total studies published in the past five years. China led in publications (54.1%), followed by Russia, Australia, and India, with Saudi Arabia having the highest citations per document (94). RSC Advances was the most active journal, publishing 8 papers from 2014 to 2023, while Applied Catalysis B: Environmental had the highest citation per document at 203. Among the three synthesis methods, chemical techniques, especially supported particles, galvanic replacement, and chemical reduction, dominated, while biological and physical methods have gained increasing interest. Iron-copper (Fe/Cu), iron-aluminum (Fe/Al), and iron-nickel (Fe/Ni) were the most frequently synthesized bimetals over the last decade.

Quality assessment / Risk of bias analysis This systematic review did not employ a specific quality assessment tool but relied on general criteria emphasizing methodological rigor, sample size adequacy, and completeness of data reporting. The review focused on studies with detailed synthesis methods, adhering to PRISMA guidelines, and considered recent research from 2014 to 2023. The initial search yielded 344 articles, 89 from WoS and 255 from Scopus, of which 291 remained after removing duplicates. Following title, abstract, and keyword screening, 76 articles were excluded, leaving 215 for eligibility assessment. Exclusions were made for articles that were inaccessible, non-English, review articles, conference papers, book chapters, or unrelated to Fe- or Al-based bimetal synthesis. Final selection resulted in 47 articles which were categorized as physical (3), chemical (42), and biological (2). To have a comprehensive scope, 75 additional articles from Google Scholar were added, bringing the total to 122, all of which were screened with the same rigorous criteria. A bibliometric analysis was alaso conducted to assess research activity on the synthesis of Fe-based and Al-based bimetals. Finally, no conflicts of interest were influencing the reported results.

Strategy of data synthesis The synthesis methods for iron-based and aluminum-based bimetallic materials were classified into physical, chemical, and biological techniques. The physical methods were further divided into mechanical alloying, electrical explosion of metal wires, sonochemical processes, radiolysis, and magnetic field-assisted laser ablation in liquid (MF-LAL). Chemical methods were categorized as chemical reduction, chemical dealloying, supported particles/nanoparticles, thermogravimetric methods, seed-mediated growth, galvanic replacement, and electrochemical synthesis. Biological methods involved the use of bio-based reducing agents and stabilizers for synthesis. Key factors such as the type of bimetal synthesized, materials used, advantages and disadvantages of

synthesis methods, and even characterization techniques were outlined and summarized in the results.

Subgroup analysis The various physical, chemical, and biological methods for synthesizing iron-based and aluminum-based bimetallic materials were further subdivided to provide a comprehensive overview of the synthesis and preparation processes. Physical methods were categorized into mechanical alloying, electrical explosion of metal wires, sonochemical processes, radiolysis, and magnetic field-assisted laser ablation in liquid (MF-LAL). Chemical methods included chemical reduction, chemical dealloying, supported particles/nanoparticles, thermogravimetric techniques, seed-mediated growth, galvanic replacement, and electrochemical synthesis. Biological methods focused on the use of bio-based reducing agents and stabilizers for the synthesis. This detailed classification allowed for an in-depth examination of synthesis techniques for Fe-based and Al-based bimetals, materials used, the advantages and disadvantages of each method, as well as characterization techniques. Additionally, the review identified common Fe-based and Al-based bimetals synthesized by researchers, emerging synthesis methods, and those gaining recent interest.

Sensitivity analysis No sensitivity analysis was performed. Among the 122 articles included in the systematic review, none were excluded due to a high risk of bias, especially those with unclear or incomplete data on synthesis methods.

Country(ies) involved Philippines, Japan, Australia.

Keywords Bimetals, iron, aluminum, physical, chemical, biological, synthesis.

Contributions of each author

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Author 2 - Carlito Tabelin - The author has contributed to the following areas: conceptualization, methodology, formal analysis, data curation, writing—review and editing, supervision, and project administration.
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