Indonesian Journal of Limnology
Vol. 04 No. 01, 2023 (1-16)
E-ISSN :2774-2571

Removal of Dyes Using PAMAM Dendrimer: A Review And Bibliometric Analysis

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Received 03 November 2023 Accepted 26 November 2023 Published 03 December 2023

DOI: 10.51264/inajl.v4i1.43

Abstract

Pollution caused by increasing industrial activities, particularly dye pollution in water bodies, has posed significant challenges for researchers. As a result, researchers have continued to prioritize the elimination of dyes, motivated by the necessity to protect water quality, and reduce the accompanying hazards. Addressing this issue has prompted various approaches, with adsorbents emerging as a promising solution. Among these adsorbents, Poly(amidoamine) (PAMAM) has shown substantial potential in the field of dye removal. This article undertook a review of published articles in this relevant domain and conducted a bibliometric analysis. A total of 36 articles were identified up to the year 2022 and various PAMAM derivatives and the dyes they removed were cataloged. The comparative analysis encompassed articles, authors, journals and countries, highlighting the importance of the research in this area. Furthermore, the article established relationships through co-citation analysis, shedding light on the interconnectedness of research in the field. To visually represent the data, VOSviewer software was employed to create maps, making the findings more accessible and comprehensible.

Keywords: Adsorbent, Bibliometric analysis, Dye, PAMAM, VOSviewer.

1. Introduction

The environment undergoes constant transformations due to daily fluctuations in its components caused by various activities. Several factors have a negative impact on the environment, posing direct or indirect threats to components of the ecosystem. Consequently, addressing environmental contamination has become a significant area of research focus. Researchers continually work on developing techniques to identify these contaminants and implement appropriate remediation methods. Water pollution is a major concern in this field, resulting from human activities and posing a severe pollution issue (Lellis *et al.*, 2019, Morin-Crini *et al.*, 2022, Fuller *et al.*, 2022). Among the numerous pollutants found in water, key contributors include suspended particles, pesticides, microbial contaminants, organic solvents, and various compounds. These contaminants enter water bodies primarily through sewage and industrial discharge, largely stemming from various industrial activities.

Synthetic textile dyes represent a significant category of pollutants that pose threats to both the environment and human health (Islam *et al.*, 2023). These dyes are commonly found in effluents from the textile industry and their production and usage contribute to water pollution due to the presence of harmful chemicals and improper disposal practices. The chemical composition of these synthetic dyes raises particular concerns. They often contain hazardous elements such as heavy metals (chromium, lead, cadmium, and mercury), aromatic amines and compounds based on formaldehyde. These substances present hazards to aquatic organisms, soil life and can enter the food chain through the process of bioaccumulation. Azo dyes (Ayed *et al.*, 2011), a specific subgroup of synthetic textile dyes characterized by the presence of one or more azo groups in their chemical structure, represent the largest class among various textile dye groups and are extensively utilized in the textile industry. Dyes have been associated with reduced photosynthesis, depletion of dissolved oxygen and the introduction of toxic effects on both plant and animal life.

When textile industry wastewater is discharged into natural water sources without adequate treatment, it can contaminate rivers, lakes and groundwater, leading to detrimental impacts on aquatic ecosystems and the safety of drinking water supplies. Therefore, it is of paramount importance to treat this wastewater comprehensively before releasing it into water bodies to prevent substantial adverse consequences.

Addressing the removal of dyes from aqueous solutions has been a significant area of focus. Below are some of the primary techniques employed for dye removal:

1.1. Coagulation: Coagulation is an effective method applied in dye removal from wastewater (Moghaddam *et al.*, 2010).
1.2. Biological treatment: This treatment utilizes enzymes (Imran *et al.*, 2015) and microorganisms (Samer, 2015) for removal of dyes.
1.3. Reverse osmosis: Thin film membranes are utilized for such treatments (Carmen *et al.*, 2012, AL – Nakib 2013).
1.4. Advanced oxidation processes: This is a commonly employed wastewater treatment process for textile wastes which primarily involves the application of hydrogen peroxide, ozone and UV radiation, either individually or in combination (Nippatlapalli & Philip, 2021, Vaiano, & Iervolino, 2018).
1.5. Adsorption: This technique mainly uses nanoparticles, nanocomposite, polymers, polymer base nanomaterials for dye removal.

Adsorption is indeed one of the highly effective techniques employed in the treatment of dye-laden wastewater. This approach relies on the transfer of soluble dyes from the wastewater to the surface of an adsorbent material. Its efficiency depends upon factors like the size and porosity of the adsorbent's surface area as well as the interaction between dye molecules and adsorbent (Carmen *et al.*, 2012, Shanker *et al.*, 2017). The most effective adsorbent materials include highly porous coal-based activated carbon (Jan *et al.*, 2021, Ahmad & Hameed, 2010), nanoparticles (Cheung *et al.*, 2009), nano clay (Mahvi & Dalvand, 2019) and polymer-based nanomaterial (Almasian *et al.*, 2015, Cui *et al.*, 2022, Bulin *et al.*, 2020).

Dendrimer-based adsorbents have demonstrated considerable promise, with Poly(amidoamine) (PAMAM) dendrimers standing out as particularly notable for water purification purposes. In 1985, Tomalia and colleagues pioneered the synthesis of the well-known dendritic macromolecule called PAMAM (Tomalia *et al.*, 1985, Tomalia *et al.*, 1990). Presently, scientists from diverse fields are devoted to developing, altering, and utilizing dendritic compounds. PAMAM, owing to its cost-effectiveness, low toxicity, and ease of production, has emerged as one of the most extensively studied dendrimers. They find their utilization in the treatment of wastewater for removal of heavy metals, organic compounds and dyes (Almasian *et al.*, 2015).

In the present work an approach has been made to review the application of PAMAM as adsorbent for the removal of dye from aqueous medium along with a bibliometric analysis of the published articles in the relevant field with the help of VOSviewer. VOS Viewer is a commonly employed tool in bibliometric research, primarily utilized for thematic, cartographic, and cluster analysis (van Eck & Waltman 2010). When utilizing VOS Viewer, scholars can efficiently explore and assess bibliometric networks encompassing authors, publications, countries, institutions, and journals.

The study will focus on identifying the various derivatives of PAMAM for the dye removal and also will touch upon the future prospects which can be applied for the new variant synthesis and its application leading to betterment of the environment.

METHODS

The selection of articles was done using the keywords PAMAM/Poly(amidoamine), Dye and adsorption/adsorbent/removal from the Dimensions database as the said database is freely accessible. The selection criteria were set with the abovementioned keywords in the "*abstract and title*" upto the year 2022 and only research articles (excluding review article) were selected for the present study work. The received results from the above methodology were further scrutinize for relevance of the topic and after exclusion of repeated data eventually 36 articles were shortlisted The bibliometric analysis was done using the mapping software VOSviewer which helps in generating the visual maps using the data for better understanding.

3. Results and Discussion

3.1. Concise Review

An examination of selected articles was conducted to gather data regarding the various types of PAMAM derivatives and their applications in dye removal (Table 1). PAMAM has garnered significant attention due to its intricate hierarchical structure and distinctive properties. Its three-dimensional branched configuration, along with abundance of functional groups, imparts valuable characteristics to dendrimers, including reactivity, adaptability of end groups, and a substantial number of internal cavities. PAMAM has emerged as a potent adsorbent for the removal of dyes. Due to its diverse range of end groups and ease of surface modification, it is a suitable choice for environmental remediation purposes. Studying the subset of articles chosen for present study reveals use of PAMAM as adsorbent can be categorized under the following points:

3.1.1. *Different generation PAMAM dendrimer*

Sadeghi *et al.* (2018) discussed the role of third generation dendrimer for the removal of reactive blue 19 dye from aqueous solution. On the other hand Nagatani *et al.* (2010) explained the 3.5 generation PAMAM dendrimer in the removal of 8-anilino-1-naphthalenesulfonic acid (ANS). Domanski *et al.* (2004) revealed application of the second, third and fourth generation (G2, G3, G4 generation) dendrimer in removal of fluorescent dyes named 12-AS and TMA-DPH.

3.1.2. *PAMAM crosslinked derivatives*

PAMAM were used as gel and prepared by crosslinking reaction between the G1.0 PAMAM dendrimer and epoxy chloropropane. PAMAM gel exhibited superior adsorption selectivity and removal efficiency towards anionic methyl orange (MO) and tartrazine (TTZ) dyes. The maximum adsorption capacity of PAMAM gel towards MO and TTZ was as high as 680.2 mg per g and 689.7 mg per g. These gels show additional property as these can be readily separated from water by filtration (Rizzi *et al.*, 2018). Rizzi *et al.* (2018) showed the preparation of hydrogel for removal of Direct Red (DR) and Direct Blue (DB) dyes.

Abdellatif & Abdellatif (2019) and Abdellatif *et al.* (2019) showed two studies using one with magnetic particles and another without it in hydrogels. hydrogels were synthesized using Iota-Carrageenan (i-carrageenan) cross-linked with PAMAM. The derivatives were tested for removal of Alphanol fast blue dye (acid dye).

Pawlaczyk & Schroeder (2021) synthesized dual-polymeric material containing poly(methyl vinyl ether‒alt‒maleic anhydride) (PMVEAMA) matrix functionalized with poly(amidoamine) (PAMAM) dendrimer. The synthesized adsorbents showed adsorption capacity 367.65 mg per g for Congo Red (Pawlaczyk & Schroeder, 2021). Another derivative was prepared via crosslinking with Poly(methyl vinyl ether-alt-maleic anhydride) and polyvinyl alcohol (PVA) for the removal of anionic dyes (Kandil *et al.* 2022). Almasian *et al.* (2019) synthesized nanofiber with PAN and PAMAM for removal of Direct red 80 (DR80) and Direct red 23 (DR23).

3.1.3. *PAMAM as host*

Nanoparticles are also known for their absorption properties and Magnetic nanoparticles acts as very good adsorbents. Researchers used the PAMAM derivatives as host dendrimer incorporated with nanoparticles. Morshed *et al.* (2020) incorporated zerovalent iron nanoparticles inside PAMAM dendrimers and tested these against crystal violet dyes. Wu *et al.* (2021) synthesized polyamidoamine dendrimer-modified magnetic nanoparticles (Gn-MNPs). The nanomaterials had shown good adsorption capacity for Sudan dyes. Afshar & Taher (2022) combined the goodness of $CuFe_2O_4$ magnetic nanoparticles with PAMAM dendrimer and incorporated these nanoparticles inside the PAMAM dendrimer. The modified dendrimers showed good adsorption capacities against alizarin reds (ARS) and brilliant green (BG) dyes.

3.1.4. *PAMAM as surface modifier*

PAMAM has also been used as surface modifier of various base materials and eventually enhanced the absorption capacity. Most of the research is based on such types of hybrid composites. Various base material include Sawdust, Chitosan, MIL-25, Aramid nanofibre, halloysite nanotubes, graphene oxide, SBA-15, mesoporous alumina nanofibers, palygorskite, silica particles. Surface of these materials was modified with PAMAM and composite materials were examined for different dyes and showed excellent adsorption capacities.

Fatemeh Banisheykholeslami et. al prepared Chitosan-PAMAM composites which showed with great adsorption capacities for Congo Red and Amido Black 10B dyes (Banisheykholeslami *et al.*, 2021).

Zhan *et al.* (2022) prepared the composite gel using Chitosan and Pamam of various generations and tested it for different dyes and found best adsorption capacities of 325.21 mg per g for rose bengal (RB) and 222.40 mg per g for sunset yellow (SY).

Kanani-Jazi & Akbari (2021) achieved an improvement in the adsorption capacity of halloysite nanotubes by functionalizing them with PAMAM. They systematically evaluated the resulting derivatives for their effectiveness in removing dyes, using Acid Red 1 (AR1) as a representative anionic dye and Methylene Blue (MB) as a cationic model dye. The removal efficiency of these derivatives was notably high, reaching 92% for AR1 and 77% for MB.

Rafi *et al.* (2018) & Rafi *et al.* (2020) successfully synthesized a nanocomposite consisting of graphene oxide (GO) modified with PAMAM dendrimers. This resulting material GO/PAMAM acted as a superadsorbent for Alizarin Red S (ARS) and Congo Red Dyes.

3.1.5. *PAMAM as hybrid composition*

Numerous hybrid compositions were developed and incorporated with nanoparticles. Such attempts were made by Hassan *et al.* (2017) who initially synthesized PAMAM/montmorillonite (MMT) and PAMAM/rice straw ash (RSA) hybrids. Subsequently, they introduced magnetite NPs into polyamidoamine dendrimer (PAMAM)/montmorillonite (MMT) or PAMAM/rice-straw-ash (RSA) hybrids to enhance their depolluting efficiency. The resulting compositions were then put to the test with xylenol orange (XO), an acidic dye, and malachite green (MG), a basic dye, demonstrating impressive adsorption capacities for both of these dyes.

Similar type of approach was made by Taleb *et al.* (2015) who synthesized co-polymer of acrylic acid and PAMAM having CuS and examined the adsorption property of resulted nanocomposite for Isma acid fast yellow G Dye.

Kurczewska *et al.* (2018) prepared the impregnated alginate bead with enhanced adsorption capabilities. Impregnation was done by encapsulation of polyamidoamine – functionalized halloysite nanotubes in alginate beads.

Table 1. List of different types of PAMAM derivatives as adsorbent

PAMAM Adsorbent	Dye	Ref.
PAMAM(Gn)	Blue 19 dye,8-anilino-1-naphthalenesulfonic acid (ANS), 12-AS and TMA-DPH	Sadeghi *et al.* (2018), Nagatani *et al.* (2010), Domański *et al.* (2004)
PAMAM Gel	Methyl orange (MO), Tartrazine (TTZ) dyes, Direct Red (DR), Direct Blue (DB)	Sadeghi *et al.* (2018), Duan *et al.* (2019)

Polyacrylonitrile (PAN)-PAMAM	Direct red 80 (DR80), direct red 23 (DR23), Methyl Orange	Almasian *et al.* (2015), Almasian *et al.* (2019), Hou *et al.* (2015)
Graphene oxide/ PAMAM	Alizarin Red S, Congo Red	Rafi *et al.* (2020), Rafi *et al.* (2018)
Magnetic Graphene oxide/ PAMAM	Crystal violet dyes, Tartrazine, Quinoline yellow, Sunset yellow, Carmoisine	Morshed *et al.* (2020), Lotfi *et al.* (2017)
Chitosan/ PAMAM	Bengal rose, Sunset yellow, Congo Red, Amido Black 10B	Banisheykholeslami *et al.* (2021), Zhan *et al.* (2022)
Magnetic Chitosan/ PAMAM	Reactive Blue 21	Wang *et al.* (2015)
Iota-Carrageenan-PAMAM and Fe_3O_4 nanoparticles- Iota-Carrageenan-PAMAM	Alphanol fast blue dye	Abdellatif & Abdellatif (2019) and Abdellatif *et al.* (2019)
SBA-15/ PAMAM	Acid Blue 62	Mirzaie *et al.* (2017a), Mirzaie *et al.* (2017b)
SAWDUST/ PAMAM	Alphanol® fast blue acid dye	Ibrahim *et al.* (2022)
MIL-25/ PAMAM	RG19, RB50, RB21, RY145, RY160 and RY39	Khosravi *et al.* (2022)
ARAMID NANOFIBRE/ PAMAM	Congo red	He *et al.* (2022)
Halloysite nanotubes/ PAMAM	Acid Red 1 (AR1) and Methylene Blue (MB)	Kanani-Jazi & Akbari (2021)
Poly(methyl vinyl ether-alt-maleic anhydride)-PAMAM	Congo Red	Pawlaczyk & Schroeder (2021)
Polyvinyl alcohol (PVA)-PAMAM	Anionic dyes	Kandil *et al.* (2022)
$CuFe_2O_4$ magnetic nanoparticles inside PAMAM	Alizarin reds (ARS), Brilliant green (BG) dyes	Afshar & Taher (2022)
Fe_3O_4 magnetic nanoparticles inside PAMAM	Sudan red dye	Wu *et al.* (2021)
Fe particles inside PAMAM	Crystal violet dyes	Morshed *et al.* (2020)
Alginate beads/ HALLOYSITE/ PAMAM	Methyl green (MG), Sunset yellow FCF (SY)	Kurczewska *et al.* (2018)
Magnetic nanoparticles inside PAMAM/ montmorillonite (MMT) and PAMAM/ rice straw ash (RSA) hybrids	Xylenol orange (XO), Malachite green (MG)	Hassan *et al.* (2017)
alpha-Fe_2O_3 nanofiber/ PAMAM	Acid Red 18, Direct Red 80	Fard *et al.* (2017)
Mesoporous alumina nanofibers/ PAMAM	Methyl Orange	Shen *et al.* (2015)
Palygorskite/ PAMAM	Reactive Red 3BS	Zhou *et al.* (2015)

Acrylic acid/ PAMAM/CuS	Isma acid fast yellow G Dye	Taleb *et al.* (2015)
Silica particles/ PAMAM	Methyl orange (MO), Eethidium bromide (EB),	Chu *et al.*, (2008)
Quartz electrode/ PSSfilm/ PAMAM and colloids/ PAMAM	4,5 Carboxyfluorescein (CF)	Khopade & Caruso (2002)

3.2 Bibliometric analysis

A total of 36 articles have been selected for bibliometric analysis to assess the significance of research conducted up to the year 2022. The visualization of this analysis is being carried out using VOSviewer software, which helps in mapping and understanding the connections and impact of the selected research articles.

3.2.1. *Publication trend*

A total of 36 publications were identified within the specified search criteria. The synthesis of PAMAM dendrimers commenced in 1985, and their application in dye removal began in 2002, initiated by the work of Khopade & Caruso (2002), who synthesized PAMAM-coated electrodes and evaluated their efficacy against CF dye. With the growing concern over dye pollution, research in this field has garnered increasing attention, as evident from the trend in paper publications over the years. Specifically, the relevant paper publication trend indicates an average of 5 papers per year, starting from 2015 (Figure 1).

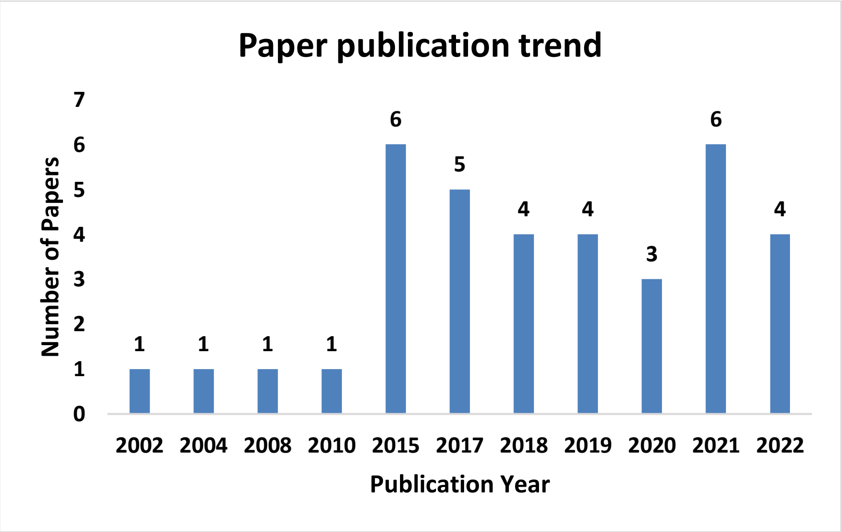

Figure 1. Year-wise paper publication trend

3.2.2. *Document citation trend*

All the selected items got minimum citation of 2 and total citation count 1124. Table 2 represent the list of titles along with their citation count. After analysing the citation chart, it was observed that 20 articles were cited more than 20 times and among them 8 were cited more than 50 times whereas 2 article were cited more than 100 times. High citation count of these articles shows the importance of their work and increasing interest in the relevant field. The most cited article is the one which is considered as first research article in the removal of dye using PAMAM adsorbent. Figure 2 represents the most interlinked cluster for citation of documents.

Table 2. List of articles with citations count more than 40.

No.	Document Title	Publication Year	citations
1	Electrostatically Assembled Polyelectrolyte/Dendrimer Multilayer Films as Ultrathin Nanoreservoirs	2002	131
2	Synthesis of polyacrylonitrile/polyamidoamine composite nanofibers using electrospinning technique and their dye removal capacity	2015	103
3	Dendrimer-based preparation of mesoporous alumina nanofibers by electrospinning and their application in dye adsorption	2015	77
4	Novel polyamidoamine dendrimer-functionalized palygorskite adsorbents with high adsorption capacity for Pb2+ and reactive dyes	2015	67
5	Design of PAMAM grafted chitosan dendrimers biosorbent for removal of anionic dyes: Adsorption isotherms, kinetics and thermodynamics studies	2021	58
6	Alginate/PAMAM dendrimer-Halloysite beads for removal of cationic and anionic dyes	2018	53
7	Removal of Anionic Dye from Aqueous Media by Adsorption onto SBA-15/Polyamidoamine Dendrimer Hybrid: Adsorption Equilibrium and Kinetics	2017	53
8	Removal of Reactive Blue 21 onto magnetic chitosan microparticles functionalized with polyamidoamine dendrimers	2015	52
9	Study of Adsorption Mechanism of Congo Red on Graphene Oxide/PAMAM Nanocomposite	2018	48
10	Facile synthesis of polyamidoamine dendrimer gel with multiple amine groups as a super adsorbent for highly efficient and selective removal of anionic dyes	2019	44
11	Solid-Phase Synthesis of Amphiphilic Dendron-Surface-Modified Silica Particles and Their Application Toward Water Purification	2008	44

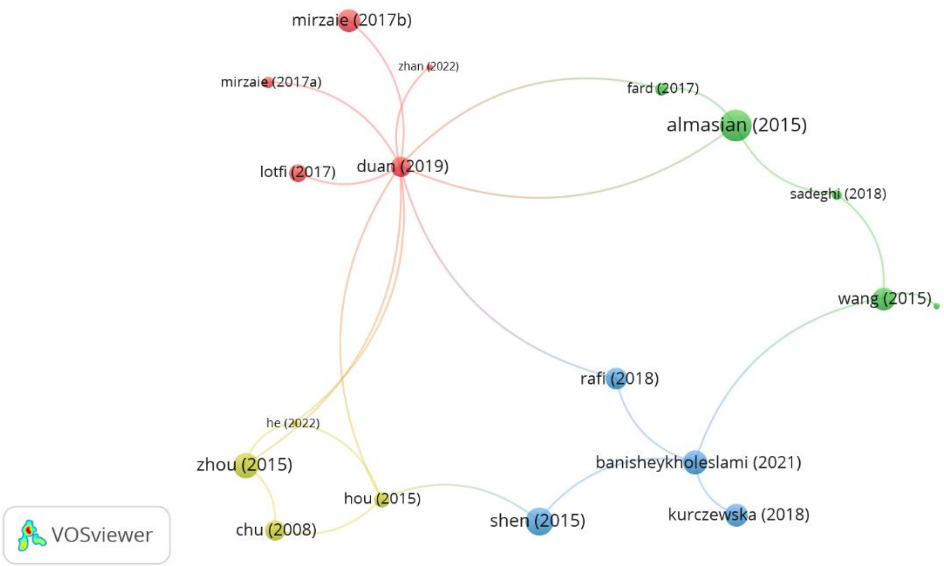

Figure 2. Most interconnected cluster for citation of documents

A subsequent co-citation analysis was conducted on the chosen relevant articles. Co-citation analysis, as a bibliometric method, identifies how often two publications are cited together, suggesting a potential association or similarity between them.

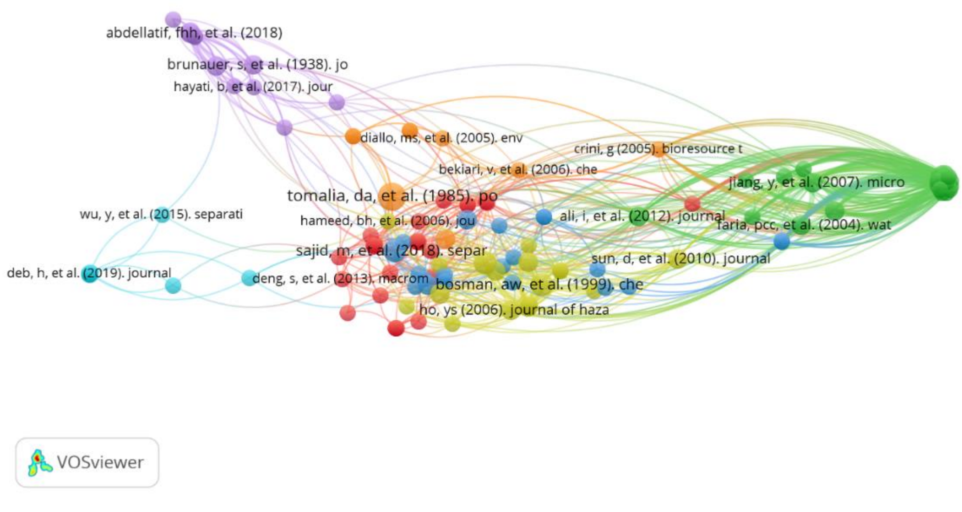

Figure 3. Co-citation cluster among titles

The strength of the co-citation relationship between publications is depicted by the thickness of the connecting lines. Figure 3 visually illustrates this co-citation network, following the criterion that sources must have a minimum of 2 citations to be included, thereby highlighting meaningful connections in the research domain.

3.2.3. *Trend analysis among Journals*

Total relevant articles were published in 32 different journals. The journal with the highest number of titles (3) was the "International Journal of Biological Macromolecules," accumulating a total citation count of 113. In contrast, the "Nano Letters" journal garnered the highest number of citations (131) despite having only one document published in it. Table 3 provides a list of the top-ranked journals based on their citation counts, while Figure 4 depicts the most interconnected cluster in the citation network.

Table 3. Top listed journals

No.	Journal Name	Documents	Citations
1	Nano letters	1	131
2	Journal of the taiwan institute of chemical engineers	2	120
3	International journal of biological macromolecules	3	113
4	Chemical engineering journal	1	77
5	Applied clay science	1	67
6	Journal of chemical & engineering data	1	53
7	Reactive and functional polymers	1	52
8	Materials	1	48
9	Chemistry of materials	1	44
10	Journal of colloid and interface science	1	44

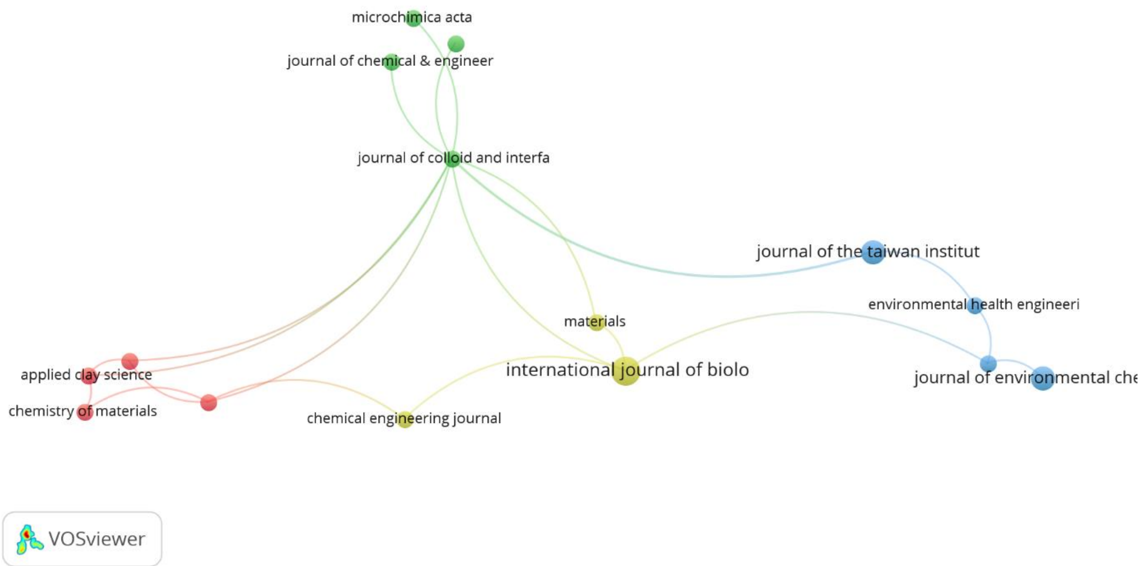

Figure 4. Most interconnect cluster of citation of journals

3.2.4. *Authors analysis: citation, co-authorship and co-citation*

A total of 134 authors contributed to the 36 articles under consideration. Khopade & Caruso (2002) received the highest citation count of 131 who co-authored the same title. Table 4 showcases the list of top-cited authors. Arash Almasian published 3 articles and received a total citation count of 127.

Table 4. Top cited authors

No.	Author	Documents	Citations
1	Ajay J. Khopade and Frank Caruso,	1	131
2	Arash Almasian,	3	127
3	Niyaz Mohammad Mahmoodi and Mohammad Ebrahim Olya,	2	110
4	Fengting li, Zehua li, Jingyi Shen, Yi-nan Wu, Bingru Zhang,	1	77
5	Maryam Mirzaie, Abosaeed Rashidi, Mohammad Esmail Yazdanshenas,	2	68

The co-citation analysis provides insights into how frequently authors are cited together, suggesting a level of association or similarity in their research. In this context, Niyaz Mohammad Mahmoodi, the author of 2 articles, has been co-cited the most times with other authors. Table 5 displays the co-citation relationships among authors, and Figure 5 illustrates the co-citation cluster among authors, with a minimum citation threshold of 5 for inclusion. This visual representation aids in identifying significant connections and relationships in authors' work based on their co-citation patterns.

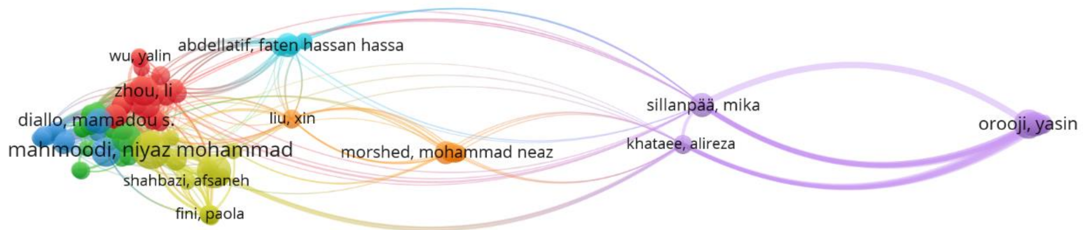

Figure 5. Co-citation cluster among authors.

Table 5. Top co-cited authors

No.	Author	Citations
1	Niyaz Mohammad Mahmoodi	26
2	Vahid Vatanpour	22
3	Li Zhou	15
4	Faten Hasan Abdellatif,	11
5	Mohammad Neaz Morshed	10

3.2.5. *Countries analysis: paper publication and citation analysis*

A total of 13 countries contributed in the relevant research area, top 5 countries list is mentioned in Table 6. An analysis shows Iran is associated with maximum paper publication in total 11, followed by China with 9 publications. Egypt, France and Poland stand at third, fourth and fifth position with total articles 6, 3 and 3 respectively. Another approach was done in Table 7, where a list of top countries is mentioned created on the basis of citations count. Again Iran and China are leading the chart with maximum citations 369 and 310 respectively. Most prominent in the list is Germany which is on third position with 131 citations for 1 article only indicating the importance of work.

Table 6. List of top 5 countries published maximum articles.

No.	Country	Documents	Citations
1	Iran	11	369
2	China	9	310
3	Egypt	6	130
4	France	3	70
5	Poland	3	79

Table 7. List of top 5 countries with maximum citations.

No.	Country	Documents	Citations
1	Iran	11	369
2	China	9	310
3	Germany	1	131
4	Egypt	6	130
5	Poland	3	79

4. Conclusions

A total of 36 articles were selected which only deal with the relevant area of title of the paper. The review of articles underscores the versatility of various PAMAM derivatives in effectively removing different types of dyes. The highest potential for dye removal was often observed in composite derivatives that harnessed the synergistic effects of multiple components, with PAMAM dendrimers playing a key role. Furthermore, there is a notable trend in research towards the development of magnetic nanocomposites. These nanocomposites inherit the advantageous property of easy removal after use, making them promising candidates for practical applications in dye removal and environmental remediation. This represents an exciting advancement in the field of adsorption and pollutant removal technologies.

Bibliometric analysis shows the detailed explanation for the various articles, authors, countries associated, citation and co-citation analysis. Title “Electrostatically Assembled Polyelectrolyte/Dendrimer Multilayer Films as Ultrathin Nanoreservoirs” authored by Ajay J. Khopade and Frank Caruso proved as one of the most important articles with maximum citations 131 and emerged as the initiator to start the trend. International journal of biological macromolecules stands out as journal with maximum 3 articles published whereas Nano letters received the maximum citations. Moreover, it's noteworthy that countries like Iran and China have made substantial contributions to relevant research. This is evident not only from the number of papers published in these countries but also from the high citation counts associated with their research.

The analysis of relevant articles leads to the conclusion that research in the field of using PAMAM derivatives for dye removal is continuously growing, primarily due to the increasing pollution driven by population growth and industrialization. It's evident that there remains untapped potential in this area, where PAMAM can be utilized as a hybrid component in many novel composites and tested with various other dyes.

Furthermore, there are opportunities to explore established compositions with derivatives for dyes that have not been previously examined, which could potentially yield improved results. This review article, coupled with bibliometric analysis, can serve as an epicentre to inspire researchers to follow and contribute to this emerging trend, thereby facilitating the development of new hybrid materials and solutions for effective dye removal and environmental remediation.

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