




REVIEW

Trends in Sediment Modeling Research and Their Ecological Implications for Ecosystem Sustainability: Web of Science Bibliometric Analysis (2006–2025)

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ABSTRACT

Sediment transport and deposition in rivers, lakes, and reservoirs are influenced by both natural processes and human activities. Excessive sediment accumulation in clarifiers reduces efficiency, increases turbidity, and deteriorates water quality. Despite growing research, there is limited bibliometric evidence on global trends and methodological approaches in clarifier modeling. This study addresses this gap by conducting a bibliometric analysis of sediment transport and turbidity management research from 2006 to 2025. Data were retrieved from the Web of Science Core Collection using the keywords “Computational Fluid Dynamics (CFD)” and “sedimentation tank.” A total of 110 publications were systematically reviewed to identify thematic patterns, leading authors and institutions, and influential journals. The results show that China and India are the most active contributors, with the National Institute of Technology (India) ranking as the top institution (7 publications). Approximately 90% of studies employed CFD or

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related mathematical and hydrodynamic models to investigate sediment behavior and flow dynamics. Water Research emerged as the most influential journal in this domain. This review demonstrates that clarifier research remains technically oriented, dominated by engineering and hydrodynamic modeling, while ecological perspectives are gradually emerging. The findings provide a clearer understanding of global research directions and highlight the need for cross-disciplinary collaboration to strengthen ecological applications of sediment modeling.

Keywords: CFD; Sedimentation Tank; Ecosystems; Review; Bibliometric Analysis; Web of Science; VOSviewer; Biblioshiny

1. Introduction

Efficient management of sediment-laden flows in hydraulic and water-treatment structures has become a critical engineering priority, particularly as many existing systems experience declining performance due to excessive sediment accumulation^[1]. One of the major challenges in large water reservoirs is the accumulation of sediments in clarifiers and the increase in water turbidity. These phenomena reduce the efficiency of sedimentation tanks and negatively impact water quality. As a result, scientists are increasingly focusing on studying sediment transport and turbidity dynamics in clarifiers using advanced modeling techniques. This study employs bibliometric analysis to investigate the significance of sediment-related research. The key challenges in clarifier and sedimentation-tank research arise not from broad climatic considerations but from the fundamental mechanics of particle transport, hydrodynamic behavior, and internal flow organization^[2]. Rising temperatures—basically the climate change side-effects nobody asked for—hit ecosystems pretty hard, especially in tropical regions and lower-income countries^[3-5]. Studies show that hotter conditions drag down farm productivity, which is a huge source of income for many of these economies. The heat messes with how crops grow and stretches out drought periods, making it tougher to sustain reliable harvests^[6]. Accurate assessment of sediment transport in surface water systems requires a thorough understanding of erosion dynamics, particle–fluid interactions, and the development of hydraulic structures within clarifiers and open channels^[7]. The dynamics and composition of river sediments, along with their significance for irrigation systems, have been the subject of sustained scientific interest for several decades. Numerous studies have focused on

understanding sediment transport mechanisms in turbulent flows, developing mathematical and conceptual models, and assessing the fractional and chemical characteristics of sediments^[8]. Despite this extensive body of research, sediment behavior in natural river systems remains a complex and actively debated topic due to the variability of hydraulic, geological, and environmental conditions. River sediments consist of solid particles generated through the weathering and erosion of rocks, soils, and organic matter. These particles are transported by river flows through channels and ultimately deposited in lakes, reservoirs, and marine environments^[9]. During transport, sediments undergo mechanical alteration, sorting, and selective redistribution under the influence of flow velocity, turbulence intensity, and channel morphology. The mechanical composition of river sediments is highly heterogeneous and includes particles of varying sizes, from coarse bed material to fine suspended fractions^[10]. From an irrigation perspective, fine-grained sediments play a particularly critical role. Their presence affects sediment deposition in canals, clogging of hydraulic structures, changes in conveyance capacity, and alterations in soil physical properties within irrigated lands. Consequently, understanding the transport, distribution, and accumulation of fine sediment fractions is essential for improving irrigation efficiency and ensuring the long-term sustainability of water infrastructure^[11]. Special attention is given worldwide to developing methods for assessing river sediment movement and calculating their distribution in irrigation systems. Technologies for cleaning hydraulic structures from sediment, managing sludge and deposits, and using them effectively are also being actively developed^[12]. Scientific research on sediments and clarifiers holds global importance^[13]. Their analysis and modeling are widely used in irrigation, drinking water supply, and

environmental protection^[14]. The study of sediments and their movement, as well as processes related to any contaminants, multiphase flows, and suspensions that create changes in water, is crucial for enhancing system performance and managing waste^[15]. Through these methods, it is now possible to gain a clearer understanding of the flow of sediments in clarifiers and the dynamics of sediment transport, as well as their impact on the system, to ensure optimal performance. Modern modeling and computational methods, including Computational Fluid Dynamics (CFD) software, have led to new approaches in dynamically analyzing fluids and sediments^[16]. Through these methods, it is now possible to gain a clearer understanding of the flow of sediments in clarifiers and the dynamics of sediment transport, as well as their impact on the system, to ensure optimal performance^[17]. Clarifiers are devices used in irrigation and water treatment systems designed to separate solid particles from liquids, and it is necessary to deeply study the sedimentation process and their dynamics to ensure their effective operation^[18]. The results showed that the baffle reduced the inlet recirculation zone and improved solid settling by channeling particles downward with higher velocity^[19]. As a result, the overall solids removal efficiency rose from 90.4% to 98.6%, which corresponded to an approximately 85% decrease in the concentration of solids in the effluent. Sedimentation tanks constitute one of the most common types of water-treatment processing units^[20]. A 3D computational model was developed to assess the dynamics of sediment movement and transport in open channels^[21]. Numerical simulations were carried out using Computational Fluid Dynamics (CFD) in ANSYS/FLUENT 16 to control heat and velocity in industrial processes^[22]. In 44% of the reviewed articles, it was found that due to the increase in sediment deposition, reservoirs and canals are losing their water intake capacity, resulting in the formation of sludge^[23]. During the sediment transport process in clarifiers, several critical issues may arise, including: incomplete settling of suspended particles, resuspension of previously settled solids due to hydraulic disturbances, and the occurrence of improper flow patterns within the clarifier^[24]. The following approaches can serve as effective solutions to these problems: mathematical and CFD (Computational Fluid Dynamics) modeling of the sedi-

ment-laden flow behavior, modeling of particle motion based on Stokes' law for various particle diameters, flow analysis using turbulence models, such as the k-epsilon and k-omega models, multiphase flow simulations^[25,26], considering interactions between water and sediment phases, experimental and laboratory validation of simulation results to ensure model accuracy, implementation of automated control and monitoring systems to continuously assess clarifier performance and improve operational efficiency^[27].

Expanding the scope of specialized studies helps provide a comprehensive view of the issues that have been addressed. Bibliometrics, scient metrics, and informatics are examples of research focused on metrics^[28]. These studies aim to understand the dynamics of various disciplines as reflected in their respective literature^[29]. Bibliometric analysis is an effective and efficient tool for examining publications within a specific field. Unlike reviewing scientific literature, which often involves both quantitative and qualitative methods and is prone to researcher bias, this quantitative approach focuses on analyzing the metadata of scientific publications^[30].

2. Materials and Methods

2.1. Literature Search Strategy

This bibliometric review was conducted using the Web of Science Core Collection, recognized as one of the most comprehensive bibliographic databases. The search was performed in January 2025. To ensure reproducibility, the following exact search string was applied:

TS = (“CFD” AND “sedimentation tank”). Here, TS (Topic Search) includes title, abstract, and keywords. The Boolean operator AND was used to identify publications that simultaneously addressed computational fluid dynamics (CFD) and sedimentation tanks. The time span was set from 2006 to 2025.

2.2. Eligibility Criteria

To guarantee relevance and methodological rigor, the following inclusion and exclusion criteria were applied: Inclusion criteria: Document type: peer-reviewed articles; Language: English; Time span: 2006–2025; Subject areas:

Engineering, Environmental Science, Ecology, Water Resources; Countries of origin: India, France, China, United States, Iran, Greece; DOI availability: only articles with a valid DOI. Exclusion criteria: Articles with only title/abstract in English but full text in another language; Publications unrelated to CFD-based sedimentation tank research; Duplicate records; Articles without DOI.

2.3. Data Extraction and Processing

The search results were exported in CSV format and initially processed in Microsoft Excel 2021 to remove duplicates and check for inconsistencies. Data were also exported in RIS format for bibliometric visualization. Analytical tools included: Excel—preliminary cleaning and descriptive statistics, VOSviewer—co-authorship networks, keyword co-occurrence, citation analysis, MapChart—

geographical distribution mapping.

2.4. Bibliometric Analysis

A total of 110 relevant publications were identified. These articles were analyzed to determine research trends, influential authors, leading institutions, and methodological approaches (RANS, LES, DEM, Eulerian). The dataset was systematically reviewed to highlight global contributions to CFD-based sedimentation tank research and its ecological implications.

2.5. Methodological Flowchart

Figure 1 presents the methodological flowchart, outlining the sequential steps: database search → screening → application of inclusion/exclusion criteria → dataset cleaning → bibliometric analysis and visualization.

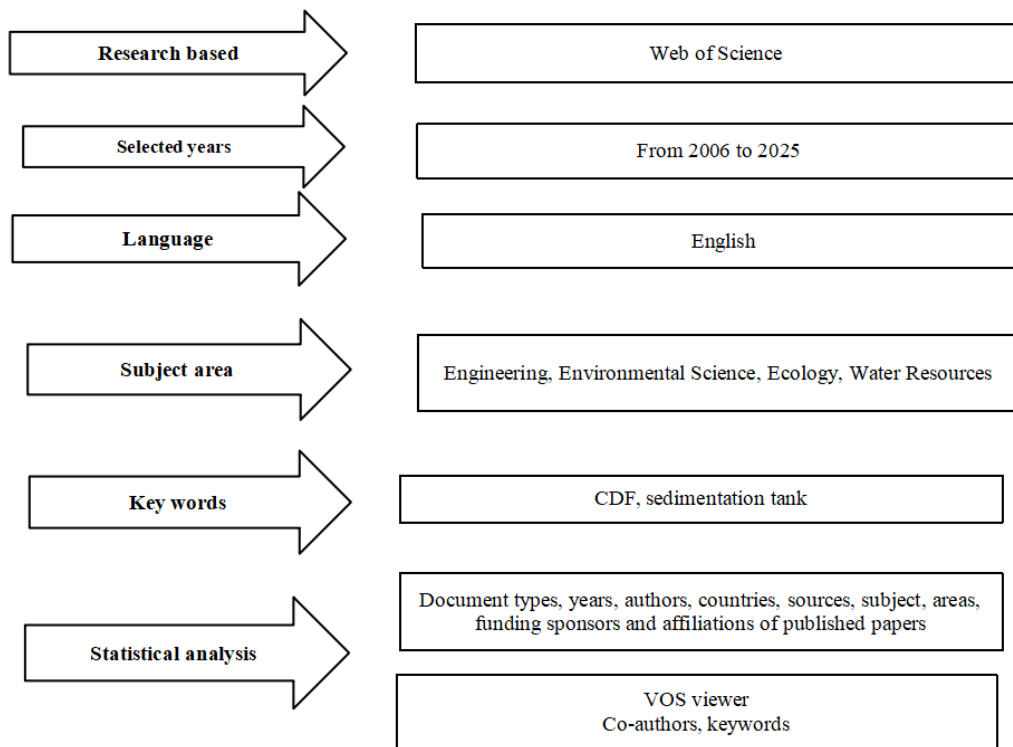


Figure 1. Methodology flowchart for the research.

3. Results and Discussion

3.1. Publication Trends on Sedimentation Tanks in Different Countries

The study of sediment transport in major basins

worldwide using CFD models demonstrates growing scientific attention. Between 2006 and 2025, a total of 110 scientific articles dedicated to sedimentation tanks were published globally (Figure 2).

For analytical clarity, the publication record can be

divided into two phases:

2006–2015: a period of relatively limited output, with modest year-to-year variation.

2016–2025: a period of more consistent activity, though the overall increase remains moderate rather than sharply accelerating.

Within these phases, certain years (2011, 2013, 2017) show small peaks in publication counts, reflecting episodic interest in hydraulic modeling. In 2020, the number of publi-

cations was higher compared to adjacent years, suggesting a temporary intensification of research activity, possibly linked to broader discussions on water resource management.

Overall, while the dataset indicates gradual expansion of research output, the evidence does not strongly support claims of “stable growth” or “sharp increases.” Instead, the trend is better characterized as incremental growth with occasional fluctuations, highlighting the need for cautious interpretation of bibliometric patterns.

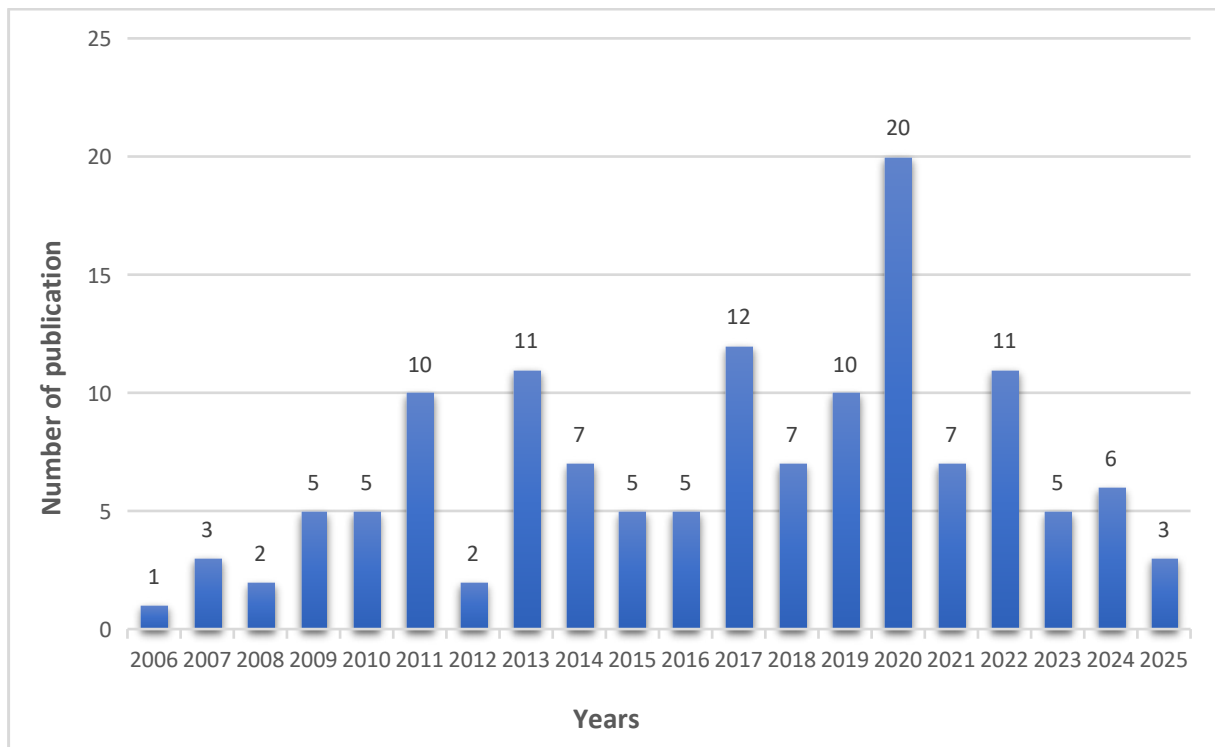


Figure 2. Global yearly publication trends on sedimentation tanks from 2006 to 2025.

3.2. Top Subject Area on Sedimentation Tank

The pie chart (Figure 3) presents the distribution of research subject areas contributing to studies on sediment-laden flow dynamics and sedimentation tank processes. Engineering (48%)—represents nearly half of the publications, reflecting the strong presence of technical and modeling approaches in this domain. Environmental Sciences and Ecology (25%)—indicates a substantial contribution from ecological and environmental perspectives. Water Resources (23%)—shows the relevance of

hydrological and resource management considerations. Mechanics (4%)—accounts for a smaller share, linked to theoretical and physical aspects of fluid-particle dynamics.

This distribution suggests that research on sedimentation tanks is interdisciplinary, with engineering approaches forming the largest proportion, while environmental, ecological, and hydrological perspectives provide complementary insights. The relatively smaller share of mechanics highlights its supporting role in underpinning theoretical foundations.

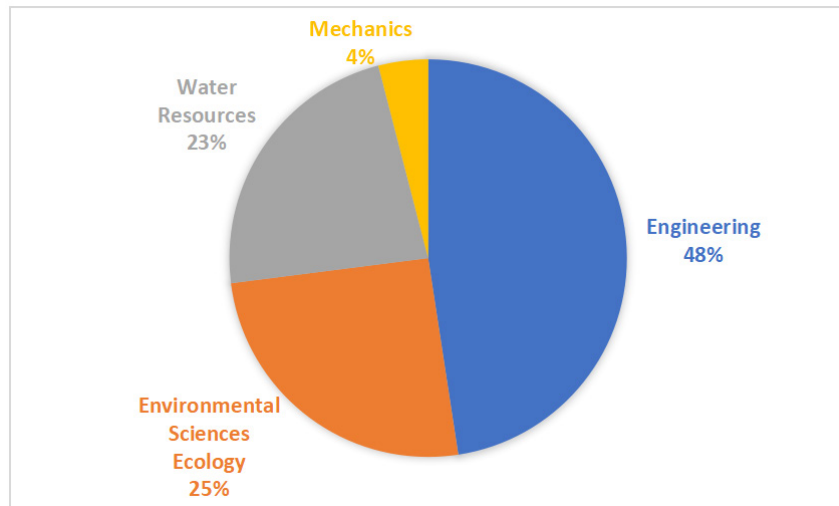


Figure 3. List of subject areas related to sedimentation tanks.

3.3. Country-Level Analysis of Sedimentation Tank Publications

Between 2006 and 2025, the ten countries with the highest number of publications on sedimentation tanks are: China (37), USA (19), England (12), France (12), Greece (11), India (9), Iran (9), Australia (6), Canada (5), and Germany (5) (Figure 4). This distribution shows that research activity is concentrated in a few countries, with

China contributing the largest share. The variation among nations may reflect differences in research capacity, funding priorities, and local water management challenges. For example, countries with large river basins or urban water infrastructure needs tend to publish more on CFD-based sedimentation tank studies.

Overall, the data indicate a global but uneven engagement with sedimentation tank research, shaped by national contexts rather than uniform international trends.

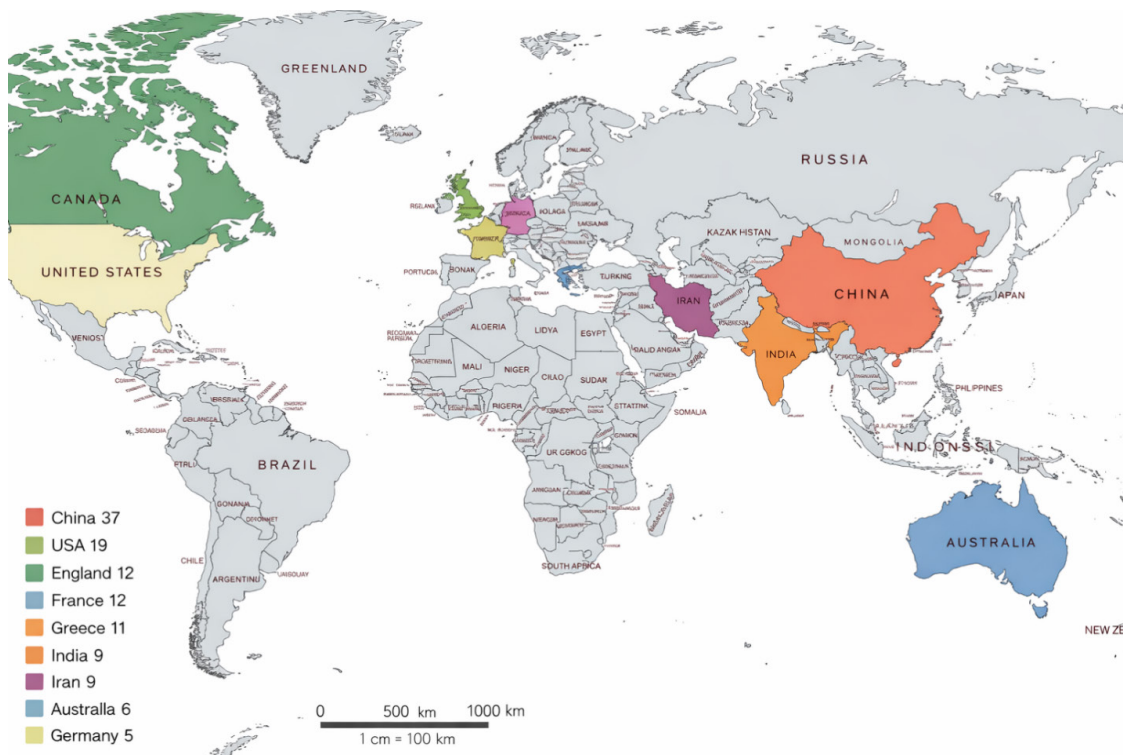


Figure 4. List of top countries on sedimentation tank.

3.4. Authors and Their Affiliated Country, Organization, and Subject Categories

Based on our research, we identified 110 authors who conducted studies on clarifiers and CFD during the period from 2006 to 2025. **Table 1** presents the top 10 authors who have published 3 or more papers in this field. Among them, Stenstrom Michael K. from the University of California, Los Angeles, who works in the field of Environmental Sciences & Ecology, leads with 5 publications related to sedimentation tanks, backed by a high H-index indicating the effectiveness and impact of his scientific work. He is followed by Gao H.W. from the Chinese Academy of Sciences, representing the Engineering field, who also has 5 publications and an H-index of 27. Other notable contributors include Dufresne M. from France, Devi Thi-

yam and Hiron K. from India—each with 5 publications; Pantokratoras A. and Gkesouli A. from Greece—each with 4; Tarpagkou R. from France with 4 publications; and Fillos J. from the USA with 3 publications.

In terms of high-performing institutions, 113 different organizations collaborated to publish 210 papers related to sedimentation processes and modeling in clarifiers. **Figure 5** presents the top 10 most active institutions based on the number of publications over the past 20 years. According to the results, these publications belong to institutions from various countries. The National University of India ranks first (with 7 publications), followed by Aristotle University of Thessaloniki in Greece (5 publications), Manipur National University (5 publications), and the University of California Los Angeles (each with 5 publications).

Table 1. List of top authors on sedimentation tank in the world.

No.	Authors	Record Count	Country	Organization	Subject Categories	H-Index
1.	Stenstrom, Michael K.	5	Los Angeles	University of California	Environmental Sciences & Ecology	46
2.	Gao HW	5	China	Chinese Academy of Sciences	Engineering	27
3.	Dufresne M.	5	France	Universite de Strasbourg	Water Resources	13
4.	Devi Thiyam	5	India	National Institute of Technology Manipur	Engineering	7
5.	Hiron K.	5	India	National Institute of Technology Manipur	Environmental Sciences	3
6.	Pantokratoras A.	4	Greece	Democritus University of Thrace	Engineering	21
7.	Gkesouli A.	4	Greece	National Technical University of Athens	Environmental Sciences & Ecology	4
8.	Tarpagkou R.	4	France	Universite Grenoble Alpes	Engineering	3
9.	Firoozabadi B.	3	Iran	Sharif University of Technology	Engineering	21
10.	Fillos J.	3	USA	City College of New York	Engineering	13

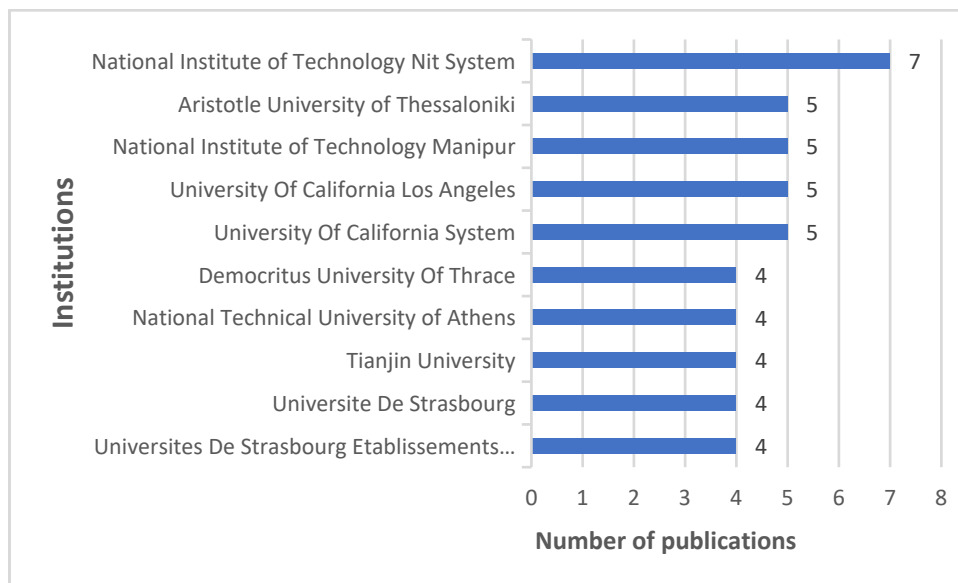


Figure 5. List of top institutions on sedimentation tank.

3.5. Top Cited Papers on Sedimentation Tank in the World

Table 2 presents data on the fifteen most cited papers worldwide on the topic of sedimentation tank. These 15

papers have collectively received a total of 894 citations. All of the articles are original research papers. Notably, ten of these publications were released during the stable growth period, with one of them published as recently as 2020.

Table 2. List of top cited publications on sedimentation tank in the world.

No.	Title	Journal	Corresponding Author	PY	TC	Doc. Type
1.	A CFD methodology for the design of sedimentation tanks in potable water treatment—Case study: The influence of a feed flow control baffle	Chemical Engineering Journal	Goula AM	2008	130	Article
2.	CFD for wastewater treatment: an overview	Water Science and Technology	Samstag RW.	2016	92	Article
3.	Development of a DEM-VOF Model for the Turbulent Free-Surface Flows with Particles and Its Application to Stirred Mixing System	Industrial & Engineering Chemistry Research	Wu L.	2018	87	Article
4.	A new settling velocity model to describe secondary sedimentation	Water Research	Ramin E.	2014	77	Article
5.	The influence of lamellar settler in sedimentation tanks for potable water treatment—A computational fluid dynamic study	Powder Technology	Tarpagkou R.	2014	57	Article
6.	Successful granulation and microbial differentiation of activated sludge in anaerobic/anoxic/aerobic (A2O) reactor with two-zone sedimentation tank treating municipal sewage	Water Research	Liu WL.	2020	57	Article
7.	Evaluation of three turbulence models in predicting the steady state hydrodynamics of a secondary sedimentation tank	Water Research	Gao HW.	2018	56	Article
8.	The effect of influent temperature variations in a sedimentation tank for potable water treatment—A computational fluid dynamics study	Water Research	Goula AM.	2008	49	Article
9.	One-dimensional modelling of the secondary clarifier-factors affecting simulation in the clarification zone and the assessment of the thickening flow dependence	Water Research	Plósz BG.	2007	48	Article
10.	Large-eddy simulations of particle sedimentation in a longitudinal sedimentation basin of a water treatment plant. Part I: Particle settling performance	Chemical Engineering Journal	Al-Sammaraee M.	2009	45	Article
11.	A CFD-based simulation study of a large-scale flocculation tank for potable water treatment	Chemical Engineering Journal	Samaras K.	2010	44	Article
12.	Numerical simulation of secondary sedimentation tank for urban wastewater	Journal of the Chinese Institute of Chemical Engineers	Fan L.	2007	41	Article
13.	Performance Assessment of Secondary Settling Tanks Using CFD Modelling	Water Resources Management	Xanthos S.	2011	37	Article
14.	Simulation of flow field and sludge settling in a full-scale oxidation ditch by using a two-phase flow CFD model	Chemical Engineering Science	Xie H.	2014	37	Article
15.	CFD based investigations on hydrodynamics and energy dissipation due to solid motion in liquid fluidised bed	Chemical Engineering Journal	Panneerselvam R.	2007	37	Article

Note: *PY—Published year, *TC—Total citation.

3.6. Journals on Sedimentation Tank in the World

This table presents some of the leading scientific journals in the world along with the total citations of articles published in them. These journals primarily publish high-quality research in the fields of water resources, chemical engineering, and industrial engineering. These journals are highly regarded among researchers due to their significant impact factor (TC).

Water Research (359 total citations), published in the Netherlands, is one of the most influential journals in the field of water quality and treatment. With a significant citation count, it is a prominent journal, often cited by researchers working on water treatment processes, wastewater management, and water resource sustainability. Chemical Engineering Journal (303 total citations), also from the Netherlands, is widely respected for its coverage of various topics in chemical engineering. Water Science and Technology (165 total citations), from the United Kingdom, focuses

on research related to water, wastewater, and environmental engineering. Industrial & Engineering Chemistry Research (98 total citations), published in the USA, is a key journal in the fields of industrial and engineering chemistry (Table 3).

Table 3. Top scientific journals and their total citation counts.

No.	Journal	Total TC	Country
1.	Water Research	359	Netherlands
2.	Chemical Engineering Journal	303	Netherlands
3.	Water Science and Technology	165	United Kingdom
4.	Industrial & Engineering Chemistry Research	98	USA
5.	Chemical Engineering Science	95	Netherlands
6.	Powder Technology	81	Netherlands
7.	Journal of the Chinese Institute of Chemical Engineers	41	Taiwan
8.	Journal of Hydraulic Engineering -ASCE	41	USA
9.	Water Environment Research	41	USA
10.	Journal of Environmental Engineering	39	USA
11.	Water Resorces Management	37	Netherlands
12.	Aqua Cultural Engineering	35	Netherlands
13.	Water Air and Soil Pollution	32	Netherlands

3.7. Co-Authorships and Keywords in Sedimentation Tank Research

Using bibliographic data from the Web of Science, co-authorship maps were generated with VOSviewer. The analysis identified a network of 419 authors, grouped into 47 items across five clusters: cluster 1 (14 items), cluster 2 (11 items), cluster 3 (9 items), cluster 4 (9 items), and cluster 5 (4 items). The total link strength was 242, with 218 links, indicating moderate collaboration across different research groups (Figure 6).

The dataset contained 1651 keywords. General and low-frequency terms were excluded to improve clarity. A

methodologically justified threshold was applied at a lower level than previously reported, resulting in 54 relevant keywords. These were distributed across five clusters: cluster 1 (17 items), cluster 2 (12 items), cluster 3 (9 items), cluster 4 (9 items), and cluster 5 (7 items). Each keyword is represented as a node, with node size reflecting its relative importance based on link strength (Figure 7).

The co-authorship and keyword analyses highlight the collaborative networks and thematic diversity in sedimentation tank research. Adjusted thresholds ensure methodological rigor and avoid overstating associations, providing a balanced view of global research patterns.

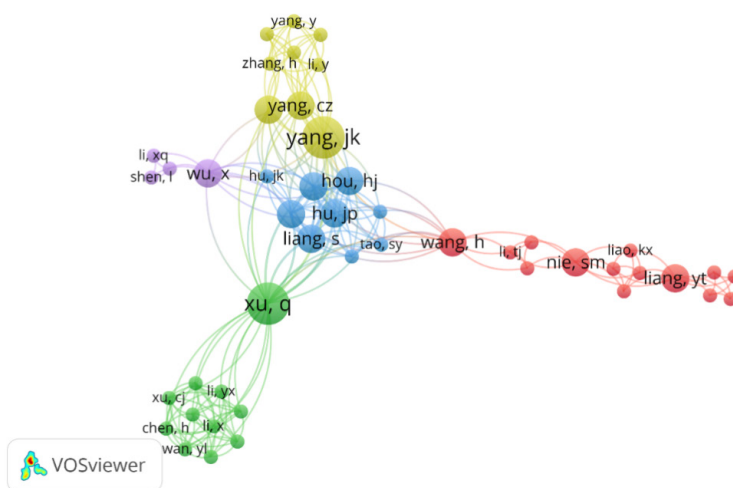


Figure 6. A network map of top co-authors based on overall link strength.

3.9. Modeling Approaches in Clarifier Research

The objective of this review was to analyze clarifiers and their numerical modeling, focusing on the most impactful research directions. Literature indicates that advanced modeling techniques—particularly CFD-based approaches—are widely applied to simulate sediment transport and flow behavior in clarifiers. These models are essential for understanding sediment dynamics, optimizing clarifier design, and improving sedimentation efficiency. Soil erosion and sediment transport models often involve limitations and assumptions^[31]. Their suitability depends on performance, spatial and temporal resolution, and application scale. Distributed models are generally preferred at the watershed level, as they capture spatial heterogeneity

in erosion potential and sediment yield. Integrated tools such as SWAT and AGWA are recommended for catchment-scale analyses, enabling estimation of net erosion and sediment output^[32].

Each sediment model has unique predictive capabilities, and selection should follow key steps: clear problem definition, evaluation of spatial scale, assessment of data availability, choice of temporal framework, identification of catchment elements, sensitivity analysis, and validation against field observations. From the dataset of 110 articles, 86 applied modeling approaches (numerical, mathematical, hydrodynamic, CFD-based), while 24 presented theoretical studies. These highlight the influence of hydrodynamic forces on sediment settling and flow movement within clarifiers (**Table 4**).

Table 4. Categorization of Modeling Approaches in Clarifier Research.

Category	Number of Articles	Description
Numerical/Mathematical	32	Models using equations and computational methods for sediment transport ^[33,34] .
Hydrodynamic (CFD-based)	28	Simulations of flow behavior and particle dynamics in clarifiers ^[35] .
Integrated Watershed Tools	14	SWAT, AGWA, and similar distributed models for erosion/sediment yield ^[36] .
Other Modeling Approaches	12	Specialized or hybrid models addressing clarifier performance ^[37,38] .
Theoretical Studies	24	Conceptual or analytical works without applied numerical simulation ^[39] .

4. Conclusion

This bibliometric review provides a structured overview of CFD-based sediment modeling and clarifier research between 2006 and 2025. The analysis of 110 publications reveals that the field is primarily shaped by engineering and hydrodynamic perspectives, with CFD approaches widely applied to study flow velocity, turbulence, and particle settling behavior. These methods have proven effective in clarifier design optimization and in advancing technical understanding of sediment-laden flows. Key findings include: Publication trends show incremental growth with fluctuations, rather than sharp or stable increases. Subject area distribution highlights engineering dominance (48%), while ecology and water resources contribute smaller but notable shares. Country-level analysis indicates uneven global engagement, with China and the USA leading outputs, reflecting differences in research capacity and national priorities. Authorship and institutional contributions are concentrated in a limited number of re-

searchers and organizations, suggesting opportunities for broader collaboration. Citation analysis shows that highly cited works emphasize CFD methodologies and turbulence modeling, reinforcing the technical orientation of the field. While ecological implications are acknowledged, the bibliometric dataset does not provide strong evidence of systematic ecological framing. Ecological perspectives appear complementary rather than central. Keyword analysis confirms that terms such as “CFD”, “flow”, and “sedimentation” dominate, whereas explicitly ecological keywords are less frequent.

The findings suggest that sediment modeling research remains technically oriented, with ecological integration emerging but not yet dominant. Future research should: Strengthen the link between CFD modeling and ecological outcomes, such as nutrient cycling and habitat integrity.

Expand cross-disciplinary collaboration to balance engineering efficiency with ecosystem sustainability. Improve methodological rigor by clarifying search strategies,

thresholds, and analytical frameworks in bibliometric studies.

In conclusion, CFD-based sediment modeling has advanced clarifier research and hydrodynamic optimization, while ecological applications are still developing. The integration of ecological perspectives represents a promising direction, but current bibliometric evidence supports a cautious interpretation. Sediment transport and turbidity management remain key global scientific priorities and are expected to retain their importance in the coming decade. A deeper understanding and modeling of sediment behavior will allow for more efficient and sustainable management of water reservoirs. Continued efforts to align technical modeling with sustainability frameworks will enhance the relevance of sediment research for ecosystem-based water management and long-term resource governance.

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Informed Consent Statement

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Data Availability Statement

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Conflicts of Interest

The authors declare no conflict of interest.

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