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Methods for evaluating total oil and grease in water

Janaina T. Goulart S. B. Oliveira[1], Sidney T. B. Oliveira-Filho[2], Rodrigo P. B. Costa-Félix[3]

[1] *Laboratory of Inorganic Chemistry, Directory of Scientific Metrology, National Institute of Metrology, Quality and Technology, Av. Nossa Senhora das Graças, 50 Xerém, Duque de Caxias – RJ, 25250-020, Brazil*
[2] *Beer Production Management, Directory of Operations, Coca-Cola Andina Brazil, Av Automóvel Clube, 4945 Taquara, Duque de Caxias – RJ, 22272-030, Brazil*
[3] *Laboratory of Ultrasound, Directory of Scientific Metrology, National Institute of Metrology, Quality and Technology, Av. Nossa Senhora das Graças, 50 Xerém, Duque de Caxias – RJ, 25250-020, Brazil*

ABSTRACT
This paper explores the correlation between the volume of scholarly publications on methodological approaches to total oil and grease (TOG) in wastewater and the implementation of public policies from 1970 to 2023, catalysed by resolutions adopted under the auspices of the United Nations. This period coincides with the emergence of global concerns about climate change and environmental protection. The analysis highlights a steady increase in publications, with research trends closely mirroring policy shifts. Initial studies in the 1970s laid the groundwork for subsequent research, as major global conferences and regulatory changes consistently spurred new publications. Notably, 68.75 % of the reviewed literature was published in the last decade, with nearly 40 % published in the past 2.5 years—reflecting the topic's sustained and increasing relevance.

Section: RESEARCH PAPER

Keywords: oil; grease; methodology; environmental; scoping review

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Corresponding author: Janaina T. G. S. B. Oliveira, e-mail: jtoliveira@inmetro.gov.br

1. INTRODUCTION

The recent emergence of international conferences addressing environmental decisionmaking and climate change has spurred new studies on solvents, oil production, and total oil and grease (TOG) determination. The formal consideration of environmental issues as policy proposals began in 1968 with the submission of a report outlining necessary programmes for the human environment. The first explicit warning regarding environmental risks was issued in 1969 [1].

A significant milestone was reached in 1972 with the establishment of the United Nations Conference on the Human Environment, which led to the constitution of the United Nations Environment Programme (UNEP). The following year, UNEP inaugurated its headquarters in Nairobi, Kenya, and held its first Governing Council meeting in Geneva. During this meeting, member states agreed to monitor, regulate, and, where necessary, prohibit trade in endangered species—an early step towards global wildlife conservation.

During the 1970s, UNEP launched its Regional Seas Programme, a critical initiative designed to contrast the accelerating degradation of marine and coastal ecosystems. This framework was swiftly adopted by sixteen Mediterranean nations, marking one of the earliest multinational efforts to address oceanic environmental challenges through coordinated policy.

The decade culminated in two groundbreaking multilateral agreements: the Bonn Convention (1979), which promoted collaborative research and conservation measures for more than 120 migratory species, and the Convention on Long-Range Transboundary Air Pollution (1979). The latter represented a historic achievement as the first legally binding international treaty to regulate cross-border air pollution, setting a precedent for regional environmental governance [1].

The 1980s marked the dawn of modern global environmental governance, with UNEP's World Conservation Strategy introducing sustainable development as a guiding paradigm. This seminal document defined the concept and contributed to its implementation into international policy discourse. As freshwater scarcity emerged as a critical challenge, the Montevideo Programme (1982) established legislative priorities, while the Montreal Protocol (1987) achieved universal UN adoption—a historic consensus on protecting the ozone layer that demonstrated the power of collective action [1].

The decade's momentum continued as UNEP partnered with the World Meteorological Organisation to embed sustainability into climate policy frameworks, and the Basel Convention (1989) implemented crucial controls on hazardous waste. These developments established environmental protection, as requiring both visionary principles and robust regulation.

The 1990s witnessed an unprecedented surge in multilateral cooperation. This decade roared to life with the birth of the Global Environment Facility (GEF), a financial engine for planetary stewardship. Then came the 1992 Rio Earth Summit—a turning point where world leaders, amid the lush backdrop of Rio de Janeiro, forged Agenda 21 and sealed two historic pacts: the Climate Change Convention and the Biodiversity Convention. These weren't just documents; they were a pact with the future.

By the decade's close, the United Nations (UN) Convention to Combat Desertification (1994) and the Rotterdam Convention (1998) had tightened the screws on ecological negligence, while the UN Global Compact (1999) challenged corporations to align profit with planetary health. The stage was set for a new millennium of accountability.

The 2000s saw environmental diplomacy leap forward with the Cartagena Protocol (2000), a bold move to manage genetically modified organisms, and the Stockholm Convention (2001), which banned the "dirty dozen" persistent organic pollutants across 176 nations. But perhaps no moment captured the zeitgeist more than 2007, when the Intergovernmental Panel on Climate Change (IPCC)—the quiet architects of climate science—stood in the spotlight in Oslo, accepting the Nobel Peace Prize [1]. Their message echoed globally: *the environment was now inseparable from peace and human survival*.

The global environmental agenda has witnessed significant milestones in recent decades, beginning with the establishment of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) during the RIO+20 conference, which provided policymakers with scientifically validated information to shape public policies. The 2014 Climate Summit marked a pivotal moment, showcasing the remarkable recovery of the ozone layer as a direct result of the Montreal Protocol's implementation. This success was followed by an even more ambitious achievement in 2015, when 195 nations reached consensus on the first universally binding global climate agreement. The momentum continued through the 2019 Climate Action Summit, which set the stage for the 2021–2030 UN Decade on Ecosystem Restoration—a critical initiative addressing the interconnected challenges of climate change mitigation, food security, water resource management, and biodiversity conservation through large-scale ecosystem rehabilitation [1].

The contentious issue of fossil fuels has been central to these discussions, with debates focusing on optimising extraction methods, improving supply chain management, implementing risk mitigation strategies, and developing viable alternatives to reduce environmental impacts. The petroleum industry faces scrutiny regarding its water management practices, specifically the handling of produced water—a byproduct of offshore oil extraction. This wastewater stream undergoes rigorous treatment to meet stringent regulatory standards before being discharged or reinjected, as its oil concentration must be reduced to legally permissible levels to minimise ecological harm [2].

Recent scientific research has increasingly focused on the environmental implications of produced water disposal from hydrocarbon operations. Regulatory definitions vary significantly across jurisdictions: while Brazil's National Environment Council (Conama) Resolution No. 393/2007 broadly classifies it as "water normally produced together with oil," the OSPAR Convention adopts a more comprehensive definition encompassing formation water, condensation water, re-produced injection water, and desalination process effluent [3], [4]. These diverging classifications reflect the ongoing challenge of establishing universal standards for managing this complex industrial waste stream, while balancing energy production needs with environmental protection imperatives.

The environmental impact of offshore petroleum operations became increasingly evident between 2009 and 2019, when annual discharges of produced water into the Northeast Atlantic exceeded 300 million cubic meters [4]. Accurately measuring these discharges presents methodological challenges, particularly regarding the quantification of TOG content in water samples. Current analytical approaches yield varying results, as each technique operationalises the definition of "oil in water" differently, highlighting the need for standardised measurement protocols [5].

To trace the development of this critical research area and assess its growing scientific importance, we conducted a comprehensive scoping review. This methodological approach systematically maps the existing body of literature, while synthesising key findings across studies. Beyond merely cataloguing evidence, scoping reviews serve valuable epistemological functions by clarifying fundamental concepts and elucidating the evolution of research methodologies within a field. The analysis not only reveals the expanding scholarly attention to produced water management, but also provides insights into how conceptual frameworks have matured since the topic first emerged in scientific discourse.

Evidence synthesis represents a rigorous methodological approach that systematically examines existing research through explicit, reproducible methods to establish a clear evidentiary foundation and identify optimal practices. This process requires strict adherence to a predefined protocol encompassing specific research objectives, well-formulated questions, and transparent inclusion/exclusion criteria. A comprehensive search strategy must be implemented, followed by protocol-guided screening and source selection, ideally conducted by multiple researchers to ensure objectivity. Methodological rigour is further enhanced by employing standardised reporting frameworks, particularly the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines with their specialised extension for scoping reviews, which promotes transparency in evaluating interventions for specific research questions [6].

Our study meticulously followed these established protocols, implementing predefined objectives, targeted research questions, and clear eligibility criteria to guide our extensive literature research and selection process. The research team, comprising multiple investigators, employed the PRISMA-ScR (Scoping Reviews) framework throughout the study, ensuring methodological consistency and transparency in examining interventions [7]. This approach differs from traditional systematic reviews in several key aspects. While systematic reviews typically commence with stringent protocol development focused on specific research questions with rigid inclusion/exclusion parameters, scoping reviews adopt more flexible criteria. Their primary aim is to map the available evidence landscape, encompassing both quantitative and qualitative studies, while synthesising findings from diverse or heterogeneous sources. The research focus is guided by PCC-based questions (Population, Concept, Context) that shape the inclusion criteria and define the scope of evidence evaluation.

The subsequent sections of this work systematically present our findings and their implications. First, we detail the methodology employed in conducting this scoping review. Next, we present the key results derived from our analysis. Finally, we explore the critical relationship between public policy frameworks and technological innovation, discussing how regulatory and policy interventions can shape advancements in this field.

2. METHODOLOGY

Systematic reviews start with the development of a rigorously structured protocol, which delineates explicit inclusion and exclusion criteria in line with the objectives of the study, thereby facilitating the investigation of a well-defined research question. Conversely, scoping reviews employ broader, more flexible criteria, with the primary objective of mapping the available evidence (spanning quantitative, qualitative, and mixed-method studies) and synthesising findings from heterogeneous or disparate sources. The research question is informed by the PCC, which not only establishes the inclusion criteria and defines the scope of inquiry, but also serves to elucidate key conceptual dimensions of the research problem. Furthermore, scoping reviews seek to examine methodological approaches for the treatment and quantification of oils and greases in wastewater, employing the PCC mnemonic strategy as an analytical guide [8].

The PCC mnemonic strategy (Problem, Concept, Context) serves to delineate and refine the research questions and objectives within a scoping review framework. In contrast to systematic reviews, scoping reviews are not bound by requirements to explicitly address outcomes, interventions, or narrowly defined phenomena of interest. Nevertheless, certain elements may remain implicitly embedded within the conceptual parameters under investigation [8].

Selection procedures were conducted in a four-stage process. The initial stage entailed the selection of descriptors for database searches. This scoping review prioritised the following keywords: *oil* AND *grease* AND *determinat** AND *wastewater*. The methodology adhered to the PRISMA 2020 guidelines [9], as delineated in Section 3.

The initial phase entails the selection and submission of search terms to multiple databases. Subsequently, *Rayyan* (i.e., a pioneering semi-automated application utilising cloud-based architecture) streamlines the identification and screening of eligible studies for systematic reviews. This platform assists researchers in addressing challenges commonly associated with conventional methodologies [10]. *Rayyan* provides collaborative research tools that establish a framework for organising, sharing, managing, and archiving systematic reviews. Furthermore, it facilitates team creation and role assignment among members, enhancing research coordination.

In the third stage, two independent researchers conducted article screening using *Rayyan* to enhance the reliability of the selection process. No temporal or linguistic restrictions were imposed, as the study aimed to comprehensively examine the scientific community's evolving interest in this topic across decades. Consequently, the review incorporated relevant literature dating back to 1971.

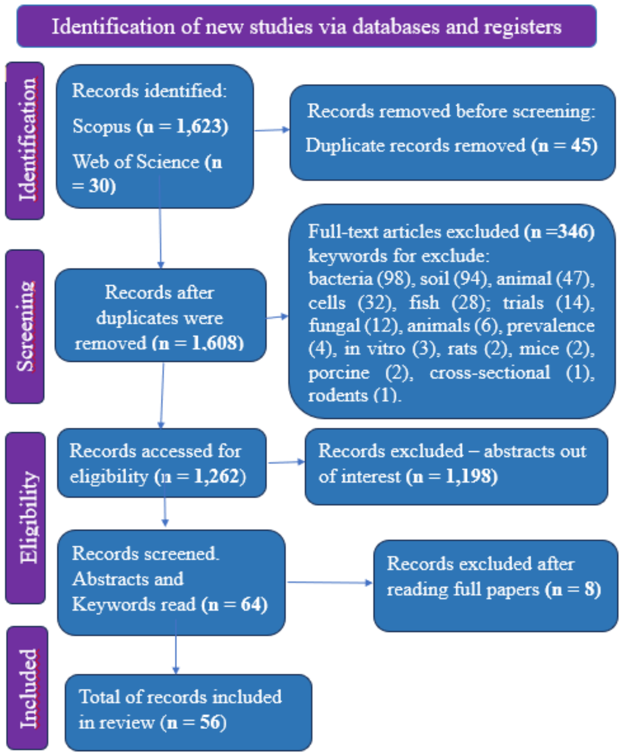

Figure 1. PRISMA-inspired flowchart illustrating the systematic selection methodology (adapted from Page et al., 2020; Sanches et al., 2018) [9], [11].

In the fourth stage, the research team systematically evaluated the selected articles by thoroughly reviewing each abstract to assess their relevance for inclusion in the scoping review. Documents failing to meet the established inclusion criteria were systematically excluded. The researchers subsequently finalised the article selection, determining which studies would be incorporated into the review.

3. RESULTS

Figure 1 depicts a systematic literature review process with sequential filtering stages, showing 1,653 records (1,623 from *Scopus* and 30 from *Web of Science*) in the initial pool. At thee first stage, 45 record duplicates were removed, and 1,608 records remained.

In the next stage, the research team conducted independent evaluations of the remaining articles. The following exclusion criteria were applied to maintain methodological focus: studies involving *rodents, bacteria, soil, animal models, cellular systems, fish, clinical trials, fungal organisms, porcine subjects, rats, mice, in vitro experiments, prevalence studies,* and *cross-sectional analyses*—all domains primarily associated with biological research applications. Conversely, the inclusion criteria comprised: *petroleum hydrocarbons, lubricants, produced water, comparative analyses, total oil and grease (TOG) measurements, standardized methodologies,* and *metrological approaches.* So, 346 records were subject to keyword exclusion, 1,262 records remained, and 1,198 records were excluded by scope-based exclusion.

Inter-rater reliability analysis highlighted discrepancies regarding the suitability of 38 publications. To resolve this divergence, a third, independent reviewer was consulted. Through this adjudication process, 12 publications were ultimately retained for full-text examination. A clear "funnel effect" emerged, with the sharpest drop occurring during eligibility assessment (94.9 % of reports excluded due to out-of-scope abstracts) with 64 final studies included to read (3.87 % of the initial pool).

The "funnel effect" represents a fundamental methodological framework employed across the research. It characterises a systematic, iterative process of progressive refinement, through which an initially expansive dataset or population undergoes sequential filtration to yield a rigorously vetted subset of optimal relevance and quality.

This procedure ensures methodological rigour through the elimination of extraneous variables and mitigation of selection biases, thereby enhancing the validity and precision of outcomes and it optimises resource allocation by strategically concentrating analytical efforts and capital expenditures on the most substantively significant elements.

Figure 2 presents the temporal distribution of the 56 studies included in this systematic analysis. The data reveal that scholarly investigation of TOG measurement methodologies originated in the 1970s, emerging shortly after the inaugural United Nations Environment Programme (UNEP) conference in Stockholm (1972).

A marked escalation in research output became apparent post-1996, temporally aligned with the United Nations Conference on Environment and Development (Rio de Janeiro Earth Summit). The data further demonstrate a pronounced surge in publication activity around 2011, which correlates with the implementation of stringent global regulations managing TOG measurement standards between 1990 and 2010. Subsequently, the Rio+20 United Nations Sustainable Development Conference (2012) established an international platform dedicated to biodiversity conservation, significantly enhancing the availability of evidence-based policy frameworks addressing petroleum hydrocarbon monitoring.

Figure 3 demonstrates a pronounced exponential growth pattern across successive decades. The initial phase shows relatively modest progression, potentially due to the limited societal recognition of environmental and climatic concerns during the early period. Subsequent decades reveal accelerated growth trajectories, correlating with heightened global awareness and concomitant demands for scientific investigation of these critical issues.

Environmental conservation and climate change mitigation bear existential significance to human civilisation. Historical records indicate that nascent recognition of the interconnectedness between atmospheric, aquatic, and terrestrial systems predated contemporary environmental movements. This awareness was notably propelled by Clair Patterson's seminal 1940s research, documenting the public health hazards of lead additives in petroleum products.

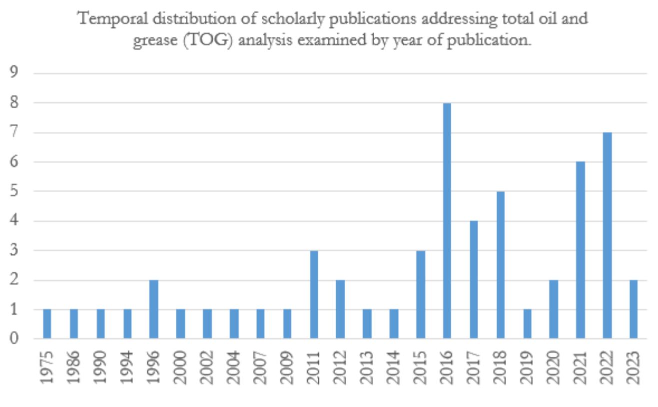

Figure 2. Temporal distribution of scholarly publications addressing total oil and grease (TOG) analysis examined by year of publication. since 1975 after mining and discussion about conflicts.

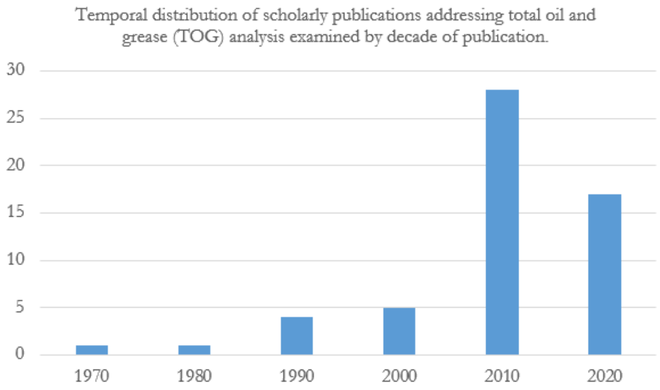

Figure 3. Temporal distribution of scholarly publications addressing total oil and grease (TOG) analysis examined by decade of publication.

4. DISCUSSIONS

Attempting to attribute the exponential growth in environmental impact studies and measurement methodologies to a single causal factor would constitute a problematic oversimplification of this complex phenomenon. The development of this research field has instead been shaped by numerous interconnected influences.

A historical analysis of scholarly literature reveals that significant global events have consistently served as catalysts for shifting societal perceptions of environmental issues. During the 1970s and 1980s, while growing environmental awareness became evident worldwide, substantive policy measures addressing specific concerns, such as oil production-related water pollution, remained limited. This early stage of environmental consciousness is reflected in the relatively modest volume of academic publications from this period examining such specific environmental impacts.

In the Brazilian context, the 1972 Stockholm Conference proved particularly influential, fostering ecological awareness that became institutionalised through landmark legislation. Two critical legal frameworks emerged from this process: the National Environmental Policy (1981), which mandates the "preservation of ecological balance while recognising the environment as a public good requiring collective protection and stewardship", and provisions enabling collective legal action for environmental damages through public civil lawsuits [12].

The Chernobyl disaster in the late 1980s starkly demonstrated the perils of modernity and the concept of a "risk society", revealing how technological systems had irreversibly intertwined ecological and societal vulnerabilities. This catastrophe underscored that environmental threats are no longer confined by borders; rather, systemic failures—not merely human errors—can amplify risks into large-scale destruction. In its aftermath, rigorous hazard assessment gained prominence, necessitating advancements in measurement instruments and methodologies to address these complex challenges [13].

During this period, Brazil's 1988 Federal Constitution formally recognised the right to a healthy environment as both a legally protected collective good and an essential individual right [12]. This constitutional guarantee laid the groundwork for subsequent environmental governance frameworks.

The 1992 Earth Summit (ECO-92) marked a turning point, with international commitments to curb CO_2 emissions, safeguard water resources, and regulate toxic waste. These agreements catalysed substantive public policies worldwide, as reflected in the surge of academic literature analysing these developments (Figure 2 and Figure 3) [14].

The early 2000s witnessed significant policy advancements, with the ratification of multiple environmental measures during the 2002 Rio+10 conference in South Africa. The growing recognition of climate change as a systemic global risk needed novel conceptual frameworks for risk assessment and the establishment of more robust regulatory structures. This paradigm shift exposed the long-term ecological consequences of industrial modernisation, which historically operated under production models that systematically externalised environmental costs.

The subsequent proliferation of environmental policy initiatives across various nations during this period correlates strongly with increased scholarly attention to these issues, as highlighted by publication trends shown in Figure 2 and Figure 3 [15]. However, the 2009 COP 15 conference revealed stark disparities between scientifically grounded public expectations and the limited political commitments achieved through international negotiations [14].

Within Brazil's regulatory landscape, the implementation of the National Solid Waste Policy mandated comprehensive waste processing prior to disposal, while establishing a federative model of environmental responsibility distributed across federal, state, and municipal jurisdictions [15]. This policy framework, particularly initiatives spearheaded by CONAMA, stimulated domestic scientific production in environmental monitoring. Notably, Brazilian researchers contributed 8 of the 26 global publications (2010–2019) on total oil and grease quantification methods [15], reflecting both the nation's growing scientific capacity and the strategic economic importance of petroleum derivatives to its trade balance and macroeconomic stability.

The 2022 UN Climate Change Conference (COP 27) marked a significant milestone, with 150 nations formally committing to advance Sustainable Development Goal 14 (SDG 14)—an international framework focused on marine conservation and the sustainable utilisation of oceanic resources [16]. Within the scholarly discourse on this critical environmental issue, Brazil has emerged as a notable contributor, accounting for 7 of the 24 relevant publications identified in this research domain over the past quadrennial period.

Empirical observations during the global pandemic revealed measurable environmental improvements, including enhanced marine water quality and substantial reductions in urban atmospheric pollution levels. These positive ecological developments occurred concurrently with a marked decline in global fossil fuel production and consumption patterns, suggesting a potential correlation between anthropogenic activity and environmental degradation.

5. CONCLUSIONS

This scoping review systematically examined the historical progression of methodological approaches for TOG quantification in aqueous environments over a half-century period (1970–2023), analysing both global trends and the specific Brazilian context. The findings demonstrate that legislative frameworks and governmental policy directives have served as primary drivers of methodological advancements in this field, while contemporaneous developments in climate science have progressively informed international environmental policymaking.

Notwithstanding these significant scientific and policy achievements, our analysis reveals a persistent disconnection between technological progress and tangible societal benefits, even following the implementation of innovative regulatory measures and technical improvements. This discrepancy underscores the critical need for governmental initiatives to pursue two-fold objectives: *i)* fostering research into sustainable, alternative energy sources, while *ii)* optimising production methodologies for existing fossil fuel technologies.

As previously stated in the introductory section of this paper, a forthcoming study will comprehensively examine the methodologies and research developments spanning the period from 1970 to the present.

AUTHORS' CONTRIBUTION

J. T. G. S. B. O. conceived the presented idea. R. P. B. C. F. encouraged J. T. G. S. B. O. to investigate how this issue became interesting to oil technology, and supervised the findings of this work. J. T. G. S. B. O. developed the theory and carried out the PRISMA method. J. T. G. S. B. O. and S. T. B. O. F. mined the papers. J. T. G. S. B. O. took the lead in writing the manuscript. All authors provided critical feedback and helped shape the research, analysis, and manuscript.

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