

ADDRESSING MICROPLASTIC POLLUTION IN MALAYSIA'S WATER SUPPLY: REGULATORY GAPS, TECHNOLOGICAL CHALLENGES, AND LESSONS FROM GLOBAL PRACTICE

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Abstract: Microplastics are defined as plastic particles smaller than 5 mm. It has emerged as a significant threat to water quality, posing risks to public health and environmental sustainability. In Malaysia, the issue with microplastics is exacerbated by rapid industrialisation and urbanisation, which contribute to increasing plastic waste. Despite growing concerns about microplastics in drinking water, the initial study found that the country's regulatory framework lacks specific guidelines for addressing this pollutant. This study employs doctrinal legal analysis, supported by desk-based research, to assess the extent to which the legal framework regulates microplastic pollution in Malaysia's water supply. The findings of this study reveal that Malaysia's current regulatory mechanisms are insufficient to manage microplastic contamination. This article recommends adopting international best practices such as the European Union's Drinking Water Directive, in order to establish clear thresholds for microplastics. Additionally, it calls for the integration of advanced filtration technologies and the application of the precautionary principle to address microplastic risks proactively. These reforms are important to safeguard Malaysia's water quality and ensure public health protection in the face of this emerging environmental threat.

Keywords: Microplastics, water quality regulation, Malaysia, drinking water, water supply.

Introduction

The infiltration of microplastics into drinking water sources has emerged as an important environmental and public health issue worldwide. Microplastics are defined as plastic particles smaller than 5 mm in size which originate from various sources, including industrial processes, packaging, cosmetic products, and the degradation of larger plastic items (Noor *et al.*, 2024). A recent study has highlighted that microplastics in drinking water could originate from both municipal and bottled water supplies, with varying degrees of contamination depending on factors such as treatment methods and packaging materials (Wong *et al.*, 2023). This further emphasises the importance of effective regulatory frameworks to ensure safe drinking water. Globally, attention to microplastics in drinking water has increased, leading the World Health Organisation (WHO) to assess the potential health impacts and

establish guidelines on microplastics in drinking water (WHO, 2024).

Nowadays, Malaysia has experienced rapid industrial growth and urbanisation, resulting in increased plastic waste generation, which significantly contributes to the presence of microplastics in the environment (Noor *et al.*, 2024). Numerous studies have reported that Malaysians are increasingly consuming microplastics through food and potentially water (Malay Mail, 2024). While the global community has begun to recognise and address the issue of microplastic contamination in water systems, Malaysia lags in developing specific regulatory measures to mitigate this risk (Usman *et al.*, 2022). Despite this growing concern, the regulatory framework for monitoring and managing microplastics in Malaysia's water supply remains underdeveloped. For example, while other countries have enacted Safe Drinking

Water Acts as legal frameworks to regulate water quality, Malaysia is still in the planning stage. The absence of microplastic-specific guidelines within Malaysia's existing water quality standards highlights a critical gap in the country's environmental governance. However, the Malaysian government has recently taken steps to address this issue. Recently, the Deputy Prime Minister announced that Malaysia is studying the impact of microplastics and other new pollutants on water quality in river basins (Malay Mail, 2024). This initiative indicates a growing recognition of the need to understand and address the risks posed by microplastics to Malaysia's water supply. There may be strong reasons for Malaysia to enact the Safe Drinking Water Act finally.

Research Objectives

The article aims to analyse Malaysia's current academic discussion and regulatory and institutional frameworks for addressing microplastic pollution in drinking water and propose recommendations for enhancing Malaysia's water quality regulation.

Research Question

The primary research questions include:

- (1) How do microplastics impact the water supply and quality in Malaysia?
- (2) How effective is Malaysia's regulatory framework in addressing microplastic pollution in drinking water?

Significance of the Study

This research is significant for several reasons, particularly in its contribution to both academic research and policy-making in Malaysia's water sector. First, it addresses a critical regulatory gap in Malaysia's water quality governance by examining the absence of specific standards for microplastic contamination within the National Drinking Water Quality Standards (NDWQS) as well as the protection of water pollution provided under the Environmental Quality Act

1974 (EQA 1974) and Water Services Industry Act 2006 (WSIA, 2006). This gap poses risks to public health, given the increasing presence of microplastics in both treated and raw water sources. Based on these shortcomings, the study provides a comprehensive legal analysis that has not been previously conducted in Malaysia's regulatory context.

Second, the research contributes to the global discourse on emerging contaminants, specifically microplastics, by offering a localised perspective from a developing country. The findings will not only enrich the academic understanding of how microplastics affect water quality but also provide policy recommendations that could be applied beyond Malaysia, especially in other Southeast Asian countries facing similar challenges.

Third, this study is directly aligned with Malaysia's commitment to the United Nations Sustainable Development Goals (SDG 6: Clean Water and Sanitation). It supports Malaysia's efforts to improve environmental sustainability and public health by focusing on the regulatory and institutional mechanisms needed to ensure safe drinking water.

Methodology

This study employs a doctrinal legal analysis approach, supplemented by desk-based research to critically examine the regulatory framework concerning microplastic contamination in Malaysia's water supply. The primary method is doctrinal analysis, where relevant statutes, regulations, and legal instruments governing water quality in Malaysia such as the Environmental Quality Act 1974, the Water Services Industry Act 2006, and the National Drinking Water Quality Standards (NDWQS) are scrutinised. This legal analysis focuses on identifying the gaps in existing regulations regarding microplastics, with particular attention to their absence from current water quality standards. Besides, a thorough review of secondary literature, including academic studies, government reports, and relevant policy documents supports the legal analysis.

The desk-based research provides insights into the technological challenges of microplastic removal from water systems and examines the regulatory approaches adopted by other countries.

Although the study draws from global practices, it does not engage in a detailed case study of any specific country. This study also conducts a regulatory gap analysis to evaluate Malaysia's current legal framework and its effectiveness in addressing microplastic contamination in water systems. This analysis highlights the absence of microplastic-specific standards within the NDWQS and identifies shortcomings in monitoring and treatment practices. Through this analysis, the study suggests areas where Malaysia's regulations can be strengthened, referencing global examples to highlight possible improvements. The study relies primarily on secondary data, including academic literature and reports related to microplastics and water quality regulation. While empirical data on microplastic concentrations in Malaysia's water supply are limited, the study draws on available global research to support the legal analysis. The lack of primary empirical data is acknowledged as a limitation of the research.

Literature Review

Global Overview of Microplastics in Drinking Water

Microplastics, tiny bits of plastic smaller than five millimetres, have rapidly become a major concern for both the environment and public health. At first, most of the research focused on how these particles affect marine life, but now, it is clear that microplastics are everywhere, even in freshwater systems and tap water around the world (Li *et al.*, 2018; Wagner & Lambert, 2018). These particles can come from many places, like industrial activities or the breakdown of larger plastic items, and shockingly, they have been found in many of our drinking water sources. A global study by Kosuth *et al.* (2018) showed that more than 90% of bottled water from major brands contained microplastics,

which raises serious questions about the safety of our drinking water. In another study, Mason *et al.* (2018) found similar contamination in tap water globally, especially in developing countries where waste management systems are less robust. Clearly, this is a big issue we need to address because it touches on something as essential as drinking water.

However, scientists are still debating whether microplastics in drinking water are actually harmful to our health. Koelmans *et al.* (2019) argue that while microplastics are widespread, the amounts found in water are generally low. They say we need more studies to figure out the real impact on human health. The World Health Organisation (WHO, 2019) agrees, noting that microplastic concentrations can range from almost none to as much as 10,000 particles per litre, which is why we need better regulations and monitoring systems (Kumar *et al.*, 2023; Swanepoel, 2023).

Some of the most common types of microplastics in water supplies are Polyethylene (PE), Polypropylene (PP), and Polystyrene (PS), with PE being the most common (Vaid *et al.*, 2021; Bilal, 2023). What is more worrying is that these plastics can carry harmful substances like Endocrine-Disrupting Chemicals (EDCs), which could pose real health risks (Choong *et al.*, 2021). Even though there is concern about these risks, scientists still cannot agree on the true danger of microplastics, since the data can be interpreted in multiple ways.

Health Impacts of Microplastic Exposure

The health effects of microplastic exposure are still the subject of an ongoing debate and it is not an easy one to resolve. Two main concerns drive the conversation: The potential physical harm from ingesting microplastics and the possibility that these particles might carry dangerous chemicals. Despite the increasing research in this area, scientists are far from reaching a consensus, and many questions about the long-term health risks of microplastics remain unanswered (Vethaak & Legler, 2021; Alderton, 2021).

One of the most immediate concerns is the physical damage microplastics might cause once they enter the body. Prata *et al.* (2019) suggest that these particles could harm the gastrointestinal tract, possibly leading to inflammation or even disrupting the gut microbiota. Because of their tiny size, microplastics can slip into biological tissues, where they may cause cellular damage. Wright and Kelly (2017) further warn that microplastics could induce oxidative stress and cell death, potentially contributing to chronic inflammation and other health issues.

However, Koelmans *et al.* (2019) take a more cautious view, arguing that the risks might be overstated. According to their research, most microplastics likely pass through the digestive system without causing harm, thanks to the body's natural defences, like the mucus lining in the gut. They did not find any conclusive evidence that microplastics can breach the gut barrier and cause serious health problems at current exposure levels. In vitro studies have shown that while microplastics can induce changes in gut microbiota, they do not necessarily compromise the gut barrier when mediated by microbial metabolites (Fournier *et al.*, 2022).

Additionally, the reversible nature of chemical transfer from microplastics in gut environments suggests that the body's natural processes can mitigate potential risks (Nor & Koelmans, 2019). However, recent evidence suggests that microplastics can be detected in human blood, placenta, and even heart tissue, raising concerns about their systemic effects, though more research is needed to confirm causality (Leslie *et al.*, 2022; Jenner *et al.*, 2022).

Another concern is that microplastics could act as carriers for hazardous chemicals. These particles have been shown to attract Persistent Organic Pollutants (POPs) and heavy metals from their surroundings. For instance, studies by Rochman *et al.* (2013) revealed that microplastics can absorb harmful substances like Polycyclic Aromatic Hydrocarbons (PAHs) and Polychlorinated Biphenyls (PCBs). Once

ingested, these chemicals could potentially be released into the human body, increasing the risk of cancer, endocrine disruption, and other severe health effects (Smith *et al.*, 2018). This is particularly worrisome for coastal communities that rely heavily on seafood, as microplastics have been detected in fish and shellfish, making dietary exposure a real concern (Carbery *et al.*, 2018).

That said, Galloway *et al.* (2017) question just how significant these risks are. While they acknowledge that microplastics can pick up pollutants, they argue that the contribution of microplastics to overall chemical exposure is small compared to other environmental sources. Koelmans *et al.* (2019) also emphasise that many microplastics are chemically inert, meaning they are unlikely to contribute much to toxic exposure. A recent study also found that microplastics not only absorb but can also alter the chemical composition of toxins they carry, making them more bioavailable upon ingestion (Moreau, 2024).

Even though more studies are connecting microplastic exposure to health risks, there is still a lot we do not know about how these particles actually affect human health. Most of the current research focuses on animal models and there has been little direct study on humans (Feei *et al.*, 2020; Blackburn & Green, 2021). Since animals do not share the full complexity of human biology or the many ways humans are exposed to microplastics, whether through eating, breathing, or even skin contact (Gross & Enck, 2021), it is difficult to draw any firm conclusions.

Furthermore, different exposure routes might lead to different health outcomes, making it all the more difficult to figure out the big picture (Enyoh, 2023). A study from Kozlov (2024) detected microplastics in human heart tissue, raising new concerns about their potential role in cardiovascular diseases. However, researchers caution that the presence of microplastics alone does not confirm a direct causal link to disease outcomes (Galloway *et al.*, 2017).

What complicates things further is that the physical and chemical properties of microplastics such as their size, shape, and surface chemistry, significantly influence their interaction with biological systems and their potential toxicity (Smith *et al.*, 2018; Moreau, 2024). There is an urgent need for studies that reflect real-world conditions, including the types and concentrations of microplastics that people are actually exposed to (Mills *et al.*, 2023). Dissanayake *et al.* (2022) caution that much recent research does not take these variables into account, which means we might be underestimating the health risks that come with microplastic exposure. The long-term effects of constant exposure to microplastics are another big question mark.

Toussaint *et al.* (2019) stress the need for long-term studies to understand the cumulative impacts of ingesting microplastics, especially for vulnerable groups like children and pregnant women. Short-term studies do not give the full picture, particularly in places where seafood makes up a big part of the diet and marine ecosystems are heavily contaminated with microplastics. Microplastics could also interact with other environmental toxins, making their effects even worse. For example, Vaseashta *et al.* (2021) point out that microplastics and the pollutants they carry could move up the food chain, leading to greater health risks for people who consume a high amount of fish and shellfish. This highlights the need for a more comprehensive approach to study microplastics and human health, one that looks not only at direct ingestion but also at the broader environmental contexts in which these particles are found.

In short, the health impacts of microplastic exposure are complex, involving a mix of physical, chemical, and ecological risks. While some researchers, like Smith *et al.* (2018) and Prata *et al.* (2019), warn of the potential dangers, others such as Galloway *et al.* (2017) and Koelmans *et al.* (2019) downplay the risks under current conditions. Still, the growing presence of microplastics in drinking water and food supplies raises important public health concerns,

particularly in areas that rely heavily on marine resources. Moving forward, it is crucial that research takes an interdisciplinary approach and focuses on real-world conditions to understand the health risks tied to microplastic exposure fully. This kind of research will be vital for shaping public health policies and reducing the long-term impact of microplastic pollution on human health.

Treatment Methods for Microplastic Removal

As microplastics continue to show up in water systems, there has been a surge in efforts to improve water treatment technologies to tackle this growing environmental problem. Conventional water treatment methods such as coagulation, flocculation, sedimentation, and sand filtration have been the mainstay of water treatment processes for decades. These methods are designed to gather and remove particles from water. However, their effectiveness in removing microplastics, especially those smaller than 10 micrometres, remains limited. Ziajahromi *et al.* (2017) demonstrated that while larger microplastics are removed through sedimentation, smaller particles frequently bypass these processes and persist in treated water. The small size of these microplastics makes it hard for conventional filtration systems, which are usually built to capture larger particles.

Multiple studies have acknowledged the limited efficiency of traditional treatment methods. Coagulation, for example, works by adding chemicals to bind microplastics together, making larger particles that can be removed during sedimentation. However, research by Melkebeke *et al.* (2020) and Modak and Basu (2022) suggests that this process is highly dependent on the size, shape, and surface properties of the microplastics. Larger microplastic particles may be more effectively captured, but smaller particles, especially fibres could escape treatment (Kwon *et al.*, 2022). Similarly, sand filtration, while effective for larger debris, struggles to capture microplastics smaller than 100 micrometres, leading to the need for more advanced technologies.

To overcome the limitations of traditional methods, advanced filtration technologies have become a key area of focus, particularly membrane filtration systems. Enfrin *et al.* (2019) emphasise the effectiveness of Membrane Bioreactors (MBRs) and nanofiltration. MBRs combine biological treatment with membrane filtration, achieving up to 99% removal rates for microplastics in wastewater treatment plants. Schymanski *et al.* (2018) also highlight how important these advanced systems are, remarking that many microplastics in drinking water fall within the 1-50 micrometre range, sizes too small for older technologies like micro-Fourier Transform Infrared Spectroscopy (μ -FT-IR) to detect. Newer techniques like micro-Raman spectroscopy have revealed that microplastics between five and 20 micrometres are common in bottled water, underscoring the need for more sophisticated filtration technologies to catch these elusive particles.

Even though membrane technologies are highly efficient at removing microplastics, their high costs limit their use. While countries like the Netherlands have successfully integrated these technologies into their water treatment systems, developing countries like Malaysia face significant challenges in upgrading their infrastructure (Schymanski *et al.*, 2018). The cost of installing and maintaining MBRs and nanofiltration systems is a major hurdle, making it necessary to find more affordable yet effective alternatives.

Another promising method for microplastic removal is the use of Advanced Oxidation Processes (AOPs). AOPs involve the generation of highly reactive species such as hydroxyl radicals to degrade microplastics into less harmful byproducts. Ozonation and photocatalysis are two AOPs that have shown potential in addressing microplastic pollution. Wang *et al.* (2019) explored the effectiveness of ozonation, particularly in oxidising polystyrene nanoparticles, a common type of microplastic. This method effectively breaks down the particles, reducing their harmful impact. Similarly, photocatalytic methods using

titanium dioxide (TiO_2) micromotors have been investigated by Fan *et al.* (2020), showing enhanced removal efficiency due to the catalytic properties of TiO_2 . While these technologies show promise, the degradation products of microplastics, as well as their long-term impacts on human health and the environment, remain areas of concern. Further research is required to fully understand the byproducts produced during AOP treatment and their potential risks. However, according to Tang and Hadibarata (2021), ozonation has high operational costs due to its energy-intensive nature and the ongoing need for equipment maintenance.

Bioremediation techniques and the use of natural coagulants have also emerged as cost-effective and environmentally sustainable alternatives for microplastic removal. Natural coagulants such as chitosan and plant-based substances have been explored for their ability to aggregate microplastics, facilitating their removal during sedimentation (Krishnan *et al.*, 2023). In regions like Southeast Asia, where natural resources are abundant, the application of such coagulants in Wastewater Treatment Plants (WWTPs) offers a feasible solution for tackling microplastic contamination (Verma, 2023). Minimising the reliance on synthetic chemicals, natural coagulants provide an eco-friendly option for microplastic removal while simultaneously enhancing removal efficiency.

Recent innovations in microplastic removal have led to the development of biofilters (Dayal *et al.*, 2024) and bubble barrier devices (Zhang *et al.*, 2022). Biofilters utilise biological processes to capture and degrade microplastics, pilot-scale studies have demonstrated their effectiveness in polishing treated wastewater before it is discharged (Rahul & Neeta, 2023). In addition, bubble barrier devices, which create curtains of bubbles to trap floating microplastics have been implemented in various countries, including the Netherlands. These methods could be particularly useful in areas, where it is difficult to implement other type of treatment technologies.

Despite these advancements, there are still many challenges in tackling microplastic contamination in water systems. Microplastics vary widely in terms of size, shape, and chemical composition, which makes it hard to develop a one-size-fits-all solution. Economic challenges also persist, especially in developing countries where upgrading water treatment systems is costly and difficult (Iyare *et al.*, 2020). To improve efficiency, a hybrid approach combining multiple treatment technologies may be the most effective solution. Furthermore, we need to understand better the long-term environmental and health impacts of the byproducts created when microplastics are broken down. Without a clear understanding of these risks, we could inadvertently create new problems while trying to solve existing ones.

Legal Approaches in Regulating Water Quality

Water quality regulation is crucial not just for protecting public health but also for safeguarding the environment. With the global demand for clean water on the rise, legal frameworks are increasingly coming under scrutiny to ensure they can effectively protect the environment and secure access to safe drinking water. One of the legal theories that provides the need for water quality regulation is the “Public Trust Doctrine”, which holds that natural resources, including water are managed by the state for the benefit of the public, both current and for future generations. As Johnson (1989) points out, this doctrine places a legal responsibility on governments to prevent pollution and contamination, ensuring that everyone has access to clean water. Under this doctrine, water pollution could be seen as a breach of the state’s duty, since it threatens the public’s right to safe water. By using the public trust doctrine, legal systems can hold states more accountable and strengthen regulations that protect water quality.

This doctrine has been crucial in various jurisdictions, particularly in the United States. In *Illinois Central Railroad v. Illinois* (1892)¹,

the Public Trust Doctrine was set as a legal principle, establishing that states must manage natural resources, including water, in the public’s interest, preventing their misuse or privatisation. Nababan (2024) critically engages with this doctrine in the context of water resources regulation, noting that it serves not only as a legal safeguard for environmental protection but also as a tool to achieve broader social welfare goals. The doctrine compels states to maintain sustainable water resource management, aligning with the public interest by preventing exploitation that could harm collective access. This principle supports sustainable development and equitable access, reflecting the doctrine’s dual role in promoting both environmental integrity and social welfare.

Besides, the Sustainable Development Goals (SDGs), particularly Goal Six are central to the global agenda for water quality regulation. SDG Six aims to ensure the availability and sustainable management of water and sanitation for all, with specific targets related to improve water quality by reducing pollution and minimising the release of hazardous chemicals (Doan, 2023). Legal frameworks that support SDG Six are increasingly integrating principles of sustainability and equitable access into water quality regulations (Rodrigue, 2023). Countries are aligning their national laws with SDG targets by implementing stricter standards for industrial discharge and improving water treatment infrastructure (Loftus *et al.*, 2018).

In translating the public trust doctrine and SDG Six into an actionable principle, the precautionary principle has become a cornerstone in environmental regulation, particularly for managing risks associated with emerging pollutants. Its significance lies in advocating for preventive measures even when there is scientific uncertainty regarding the harm such contaminants could pose to public health and the environment (Goldstein, 2001). This measure should be taken in cases where there is uncertainty or potential for harm and

¹ 146 U.S. 387 (1892)

the proponents of the intervention must prove that it is safe before proceeding (Aronson, 2021). This is to protect individuals, the public, or the environment from unintended negative consequences.

The World Health Organisation (WHO) Drinking Water Quality Guidelines provide internationally recognised standards for maintaining safe drinking water by setting limits on contaminants like microorganisms and chemicals (WHO, 2022). These guidelines, although not legally binding are often adopted by countries as the basis for national water regulations. The precautionary principle is closely related to the WHO guidelines, advocating for preventive action even when scientific certainty about potential harm is incomplete. This principle is particularly relevant for emerging contaminants such as microplastics, which have been increasingly detected in water systems but whose long-term health impacts are not yet fully understood.

In response, the WHO has acknowledged the presence of microplastics in drinking water but maintains that current data do not indicate significant health risks at existing levels (WHO, 2019). However, the WHO also stresses the importance of further research and monitoring, reflecting a precautionary approach. The WHO guidelines encourage countries to develop legal frameworks that proactively address emerging contaminants, implementing monitoring and control measures based on potential risks to public health.

Besides, the application of this principle has been especially pertinent in the context of regulating chemical pollutants in the European Union (EU), where it is embedded in environmental legislation under the EU Drinking Water Directive (Alaranta & Miettinen, 2022). However, its effectiveness in addressing the complexities associated with emerging contaminants like microplastics requires more critical assessment, especially given the dynamic nature of environmental risks and evolving scientific evidence (Kentin, 2018).

While the EU's regulatory framework, particularly under the Drinking Water Directive, reflects a strong reliance on the precautionary principle, it has been critiqued for inconsistencies and gaps in enforcement (Dolan *et al.*, 2013). For instance, pesticide regulations under the EU's water quality standards have been questioned regarding whether they align sufficiently with the precautionary approach, with some scholars arguing that the standards might not fully account for cumulative and long-term risks posed by microplastic particles (Rodrigue, 2023). This critique points to a broader issue with how the precautionary principle is operationalised: While it mandates action in the face of uncertainty, it often lacks specific mechanisms for addressing the complexities posed by emerging contaminants, especially those that are difficult to detect and measure in water sources (Aven, 2011).

Moreover, the EU's response to microplastic pollution through its REACH regulation (Registration, Evaluation, Authorisation, and Restriction of Chemicals) demonstrates the application of the precautionary principle in controlling the use of microplastics in products (Grafe & Mieg, 2021). However, this approach is limited by the lack of comprehensive legal standards for monitoring and mitigating microplastic contamination in aquatic environments. While scientific studies increasingly suggest that microplastics pose significant risks to human health and ecosystems (Coffin *et al.*, 2022), the absence of conclusive evidence on the full scope of these risks has delayed more stringent regulatory action. This highlights a critical tension within the precautionary framework: How to balance preventive regulation with the evolving nature of scientific evidence.

One significant legal case illustrating this tension is the case C-127/02 Waddenzee Case (2004), where the European Court of Justice (ECJ) applied the precautionary principle to protect a Natura 2000 site from potential harm caused by human activities, even though the scientific evidence of harm was not definitive.

This ruling emphasised that precaution should guide regulatory decisions even in the absence of full scientific certainty, a principle that could be extended to the regulation of microplastics in water systems (Rodrigue, 2023). Nevertheless, the question remains whether such legal precedents are sufficient to address the unique challenges posed by microplastics, given their pervasive nature and potential for bioaccumulation in marine ecosystems.

Besides, the case of *Vellore Citizens Welfare Forum v. Union of India* (1996)², it is a landmark example of how the precautionary principle has been applied in Indian environmental law. In this case, the Supreme Court of India tackled the issue of severe water pollution caused by untreated effluent from tanneries in Tamil Nadu. The court ruled that, according to the precautionary principle, industries must take steps to prevent environmental harm, even if the full extent of the damage is not scientifically certain. This principle shifts the burden to the polluter, requiring them to prove that their activities are not harmful to the environment.

The court's decision to shut down non-compliant tanneries and award compensation to affected communities reinforced the idea that protecting public health and the environment must come first, particularly when the damage poses significant and potentially irreversible risks. This case underscores the importance of taking preventive actions to avoid long-term harm to ecosystems and human populations. It remains a key example of the precautionary principle in action, showing how regulatory measures should be proactive in addressing environmental risks to ensure clean water and public health.

In *R v Secretary of State for the Environment, ex parte Friends of the Earth* (1994)³, Justice Schiemann emphasised the government's obligation to rectify breaches of water quality standards under the European Drinking Water Directive as soon as possible (Purdue, 1995).

The judge highlighted the necessity of acting promptly to prevent further environmental harm, which aligns with the precautionary principle, a principle that calls for preventive action in the face of environmental risks, even when scientific certainty is not fully established. The judge's focus on the state's duty to use legislative mechanisms to mitigate risks reflects the importance of proactive regulation in ensuring public health and environmental protection, a concept equally applicable to manage emerging contaminants like microplastics.

Globally, other jurisdictions have similarly dealt with the application of the precautionary principle to water quality regulation. For example, in Canada, the Canadian Environmental Protection Act (CEPA) incorporates the precautionary principle in regulating toxic substances, yet its application to microplastics remains limited, largely due to the complexity in detecting and quantifying microplastics in water systems (Environment and Climate Change Canada, 2019).

Similarly, the United States Environmental Protection Agency (EPA) has adopted precautionary measures under both the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA) to regulate contaminants, reflecting the principles of environmental risk management even when full scientific certainty is not available. Under the CWA, the EPA enforces a system of permits (NPDES) that limits pollutant discharges into U.S. waters, effectively preventing contamination of surface waters before irreversible damage occurs (section 402, CWA). This precautionary approach ensures that industries, municipalities, and other entities control pollutants at their source, even for substances that may pose long-term or uncertain environmental risks. The CWA thus functions as a preventive legal tool, aligning with the precautionary principle by emphasising pollution control before environmental degradation is realised.

² AIR 1996 SUPREME COURT 2715

³ (1995) LTL 7/6/95

Under the SDWA, the EPA takes a similarly precautionary stance by establishing Maximum Contaminant Levels (MCLs) for drinking water systems based on emerging scientific evidence of potential health risks (section 1412, SDWA). For example, contaminants like lead, arsenic, and disinfection byproducts are tightly regulated, with regular testing and monitoring required to safeguard public health. The EPA can also act pre-emptively, setting limits, or issuing advisories for contaminants that may not yet have conclusive scientific evidence of harm such as microplastics and pharmaceuticals. This demonstrates a precautionary approach within the SDWA's framework, where the health-based standards are set to protect the public from exposure to potentially harmful contaminants, even when full risk profiles have not yet been established. In California, regulatory actions to address microplastic contamination in drinking water have followed a health-based framework that applies conservative assumptions due to uncertainties in exposure and risk assessments (Coffin *et al.*, 2022).

However, while regulatory actions are underway, comprehensive guidelines for microplastics in drinking water at the federal level in the U.S., including under the CWA are still lacking due to scientific uncertainties and challenges in quantifying microplastics. This gap highlights a critical challenge: The global legal landscape remains fragmented and inconsistent when it comes to regulating microplastics, with different countries applying varying degrees of precautionary measures based on available scientific evidence.

Critically, while the precautionary principle offers a solid legal and ethical foundation for regulating water quality amidst uncertainty, its success largely hinges on how it is implemented through specific regulations. As Aven (2011) points out, the principle suggests we should act even when scientific knowledge is incomplete, but it needs to be carefully balanced so that the regulations are both reasonable and effective. When it comes to microplastics, regulatory frameworks have to keep pace, not just with

the scientific unknowns, but also with the legal grey areas surrounding their control. For instance, while EU laws do mandate risk assessments for microplastic particles, there is still no binding legal limit for the acceptable level of microplastic contamination in water. This lack of clear thresholds creates a regulatory gap, weakening the precautionary approach (Hansson, 2020).

In conclusion, the precautionary principle remains a cornerstone of environmental law, particularly in the regulation of emerging contaminants like microplastics in raw and treated water. However, its application is fraught with challenges, including the need for more robust legal mechanisms, clear regulatory standards, and comprehensive risk assessments that reflect the evolving nature of scientific evidence. Case law such as the Waddenzee ruling provides valuable insights into how precautionary measures can be enforced, but there remains a disconnect between legal principles and regulatory practice. Moving forward, international cooperation and harmonisation of regulatory frameworks will be crucial in addressing the global threat of microplastics and ensuring that water quality regulations are fit for purpose in an increasingly complex environmental landscape.

Analysis and Discussion

Microplastics and Water Quality in Malaysia

Microplastics have become a significant concern in Malaysia's water supply, worsened by the country's growing plastic production industry, which substantially contributes to plastic waste (Sulaiman *et al.*, 2023). Studies have found alarming levels of microplastics in various water sources. For example, a study conducted in Terengganu found an average of 536 microplastic particles in tap water, highlighting just how serious this issue has become (Nor, 2023). Similarly, recent research in the Selangor River Basin detected an average of 1.44 ± 0.62 particles per litre in surface water, with fibres composing 64.3% of the microplastic

pollutants, predominantly made of polyethylene 38.6% (Noor *et al.*, 2024).

Furthermore, empirical data from various regions in Malaysia indicate widespread microplastic contamination across different environmental compartments. Table 1 presents a summary of microplastic pollution in major Malaysian rivers, estuarine sediments, and agricultural soils, derived from Sharijan *et al.* (2018), Zaki *et al.* (2021), Anuar *et al.* (2023), Praveena *et al.* (2023), Tan and Mohd Zanuri (2023), Yusif *et al.* (2023), and Noor *et al.* (2024).

These findings illustrate the widespread presence of microplastics in Malaysia's water bodies, with significant contamination detected in surface waters, sediments, and even agricultural soil. The presence of microplastics in sediments such as those found in Setia Wetland, Terengganu (5.97 items/g) reinforces the hypothesis that sediments act as long-term sinks for microplastics. Meanwhile, the discovery of microplastics in Klang Valley agricultural soil (1.5 - 6.0 particles/kg) suggests that land-based pollution sources contribute significantly to waterway contamination.

Moreover, a study on the Klang River Estuary found varying concentrations of microplastics in gastropods from residential and industrial areas, with an abundance ranging from 0.50 to 1.75 particles per gram or 0.25 to 0.88 particles per individual (Zaki *et al.*, 2021). The study revealed that 91% of the microplastics found in these gastropods were fibres, predominantly black (50%), with sizes

ranging from 30 μm to 1,850 μm and were composed primarily of polyethylene-propylene-diene (PE-PDM) and polyester. This highlights how microplastics not only persist in water but also bioaccumulate in aquatic organisms, raising concerns about their entry into the food chain.

Further government-led studies have confirmed the severity of the issue, particularly in the main river basins. Research conducted under the 12th Malaysia Plan examined microplastic contamination in Langat, Kelantan, Klang, and Sarawak River basins, finding an average microplastic abundance of 179.6 to 4,541.4 particles per litre (NAHRIM, 2024). This suggests that multiple water sources in Malaysia are significantly polluted with microplastics, making it a nationwide concern.

However, it is not just tap water that is affected, but research has also detected microplastic contamination in bottled water, with levels ranging from 8 to 22 particles per litre (Praveena *et al.*, 2022; Gambino *et al.*, 2022). These findings make it clear that both raw and treated water, including commercially bottled drinking water are vulnerable to microplastic contamination, which could pose health risks to consumers.

Despite these alarming findings, Malaysia's regulatory framework still has a significant gap in addressing microplastic pollution. While there is some awareness of the issue, there has not been much in the way of strict enforcement or the inclusion of microplastic limits in water quality standards. Currently, regulations mostly focus on chemical and

Table 1: Microplastic contamination in Malaysia's water sources (Noor *et al.*, 2024)

Location	Sample Type	Microplastic Concentration
Seberang Perai, Penang	Surface water	1,407 \pm 124.265 particles/L
Seberang Perai, Penang	Estuarine sediment	4,000 \pm 29.174 particles/kg
Langat River, Selangor	Surface water	1,464.8 particles/L
Kelantan River	Surface water	179.6 particles/L
Tebrau River, Johor	River sediment	640 \pm 80 particles/kg
Setia Wetland, Terengganu	Estuarine sediment	5.97 items/g
Klang Valley	Agricultural soil	1.5 - 6.0 particles/kg

microbial contaminants, overlooking the growing threat that microplastics pose. The lack of specific standards or monitoring mechanisms for microplastics in the drinking water supply chain highlights a bigger issue in Malaysia's environmental governance. Saipolbahri *et al.* (2022) stress the urgent need for standardised testing and monitoring procedures to get a clearer picture of how widespread microplastic contamination is across different regions.

Additionally, microplastics enter Malaysia's water supply through multiple pathways, including industrial discharges, urban runoff, and wastewater effluents (Noor *et al.*, 2024). This suggests that the microplastic issue is not limited to a single source but extends across the entire water supply chain, including rivers, coastal areas, and commercial water products. The current water treatment infrastructure, which predominantly relies on conventional filtration and coagulation processes is not specifically designed to remove microplastics (Saipolbahri *et al.*, 2022). The diverse sizes, shapes, and chemical compositions of microplastics further complicate their effective removal, allowing them to persist through treatment processes and infiltrate the water supply (Noor *et al.*, 2024).

Comparatively, microplastic contamination in Malaysian drinking water mirrors levels found in other Southeast Asian countries (Li *et al.*, 2022), highlighting the transboundary nature of plastic pollution. This regional trend underscores the need for coordinated regional efforts to address the issue, as national borders do not confine plastic pollution. The lack of such collaboration limits Malaysia's ability to manage microplastic pollution effectively and hampers broader efforts to combat this environmental challenge across Southeast Asia.

Hence, while research demonstrates the prevalence of microplastics in Malaysia's water supply, the existing regulatory frameworks and treatment processes are insufficient. There is an urgent need for comprehensive policies that address microplastic contamination across the entire water supply chain, incorporating specific standards, monitoring mechanisms, and

effective treatment strategies to protect public health and ensure water quality.

Legal and Regulatory Response to Water Quality in Malaysia

In the landmark case of *Tan Tek Seng v Suruhanjaya Perkhidmatan Pendidikan & Anor* (1996) 1 MLJ 261, Justice Gopal Sri Ram significantly expanded the interpretation of the Right to Life under Article 5 of the Malaysian Federal Constitution. He held that the right to life is not confined to mere physical existence but extends to the quality of life, which encompasses the right to a clean and healthy environment. This groundbreaking interpretation laid the foundation for recognising environmental protection as an essential part of human rights. Justice Gopal Sri Ram's interpretation of the right to life inherently connected it with environmental well-being, recognising that the state has a responsibility to maintain a safe and healthy environment for its citizens. This obligation includes ensuring access to clean and uncontaminated water, as it is fundamental to sustaining life and public health.

This case carries significant weight in the context of regulating emerging contaminants in drinking water such as microplastics. The judge's interpretation suggests that any environmental degradation or contamination that affects public health, including water pollution would be a violation of the right to life. As microplastics and other emerging contaminants become a growing concern globally, Justice Gopal Sri Ram's judgment provides a strong legal basis for advocating stricter regulation of water quality standards in Malaysia. It highlights the state's responsibility to proactively address new risks to water safety, ensuring that the public's right to clean drinking water is protected under constitutional principles. This approach opens the door for judicial intervention in cases where the state may fail to adequately regulate contaminants in drinking water, reinforcing the need for forward-thinking regulation in safeguarding public health.

Table 2: Drinking water quality standard (KKM, 2004)

Parameter	Group	Recommended Raw Water Quality	Drinking Water Quality Standards
		Acceptable Value [mg/litre (unless otherwise stated)]	Maximum Acceptable Value [mg/litre (unless otherwise stated)]
Total coliform	1	5000 MPN/100 ml	0 in 100 ml
<i>E. coli</i>	1	5000 MPN/100 m	0 in 100 m
Turbidity	1	1000 NTU	5 NTU
Colour	1	300 TCU	15 TCU
pH	1	5.5 - 9.0	6.5 - 9.0
Free residual chlorine	1	-	0.2 - 5.0
Combined chlorine	1	-	Not less than 1.0
Temperature	1	-	-
Clostridium perfringens (including spores)	1	-	Absent
Coliform bacteria	1	-	-
Colony count 22°	1	-	-
Conductivity	1	-	-
Enterococci	1	-	-
Odour	1	-	-
Taste	1	-	-
Oxidisability	1	-	-
Total dissolved solids	2	1500	1000
Chloride	2	250	250
Ammonia	2	1.5	1.5
Nitrat	2	10	10
Ferum/iron	2	1.0	0.3
Fluoride	2	1.5	0.4 - 0.6
Hardness	2	500	500
Aluminium	2	-	0.2
Manganese	2	0.2	0.1
Chemical oxygen Demand	2	10	-
Anionic detergent MBAS	2	1.0	1.0
Biological oxygen demand	2	6	-
Nitrite	2	-	-
Total Organic Carbon (TOC)	2	-	-

Mercury	3	0.001	0.001
Cadmium	3	0.003	0.003
Arsenic	3	0.01	0.01
Cyanide	3	0.07	0.07
Plumbum/lead	3	0.05	0.01
Chromium	3	0.05	0.05
Cuprum/copper	3	1.0	1.0
Zinc	3	3	3
Natrium/sodium	3	200	200
Sulphate	3	250	250
Selenium	3	0.01	0.01
Argentum	3	0.05	0.05
Magnesium	3	150	150
Mineral oil	3	0.3	0.3
Chloroform	3	-	0.2
Bromoform	3	-	0.1
Dibromoklorometana	3	-	0.1
Bromodiklorometana	3	-	0.06
Fenol/phenol	3	0.002	0.002
Antimony	3	-	0.005
Nickel	3	-	0.02
Dibromoacetonitrile	3	-	0.1
Dichloroacetic acid	3	-	0.05
Dichloroacetonitrile	3	-	0.09
Trichloroacetic acid	3	-	0.1
Trichloroacetonitrile	3	-	0.001
Trihalomethanes - Total	3	-	1.00
Aldrin/dealdrin	4	0.00003	0.00003
DDT	4	0.002	0.002
Heptachlor and heptachlor epoxide	4	0.00003	0.00003
Methoxychlor	4	0.02	0.02
Lindane	4	0.002	0.002
Chlordane	4	0.0002	0.0002
Endosulfan	4	0.03	0.03
Hexachlorobenzena	4	0.001	0.001
1,2-dichloroethane	4	-	0.03
2,4,5-T	4	-	0.009
2,4,6-trichlorophenol	4	-	0.2

2,4-D	4	0.03	0.03
2,4-DB	4	-	0.09
2,4-dichlorophenol	4	-	0.09
Acrylamide	4	-	0.0005
Alachlor	4	-	0.02
Aldicarb	4	-	0.01
Benzene	4	-	0.01
Carbofuran	4	-	0.007
MCPA	4	-	0.002
Pendimethalin	4	-	0.02
Pentachlorophenol	4	-	0.009
Permethrin	4	-	0.02
Pesticides	4	-	-
Pesticides - Total	4	-	-
Polycyclic aromatic hydrocarbons	4	-	-
Propanil	4	-	0.02
Tetrachloroethene and trichloroethene	4	-	-
Vinyl chloride	4	-	0.005
Gross alpha (α)	5	0.1 Bq/l	0.1 Bq/l
Gross beta (β)	5	1.0 Bq/l	1.0 Bq/l
Tritium	5	-	-
Total indicative dose	5	-	-

To ensure the public has access to safe drinking water, which aligns with the constitutional right as discussed in the case of Tan Tek Seng above, the Ministry of Health (MOH) issued the National Drinking Water Quality Standards (NDWQS) to ensure the quality of water. NDWQS outlines the quality parameters for drinking water, focusing on traditional contaminants such as microbial, chemical, and physical parameters (KKM, 2004) as stated in Table 2.

Table 2 indicates that microplastics are not explicitly recognised as a parameter in either the recommended raw water quality or the drinking water quality standards. Although the NDWQS encompasses a diverse array of contaminants, including microbiological elements, physical

properties, heavy metals, organic chemicals, pesticides, and radiological substances, it does not specifically address microplastics. This omission suggests that current drinking water standards do not incorporate the emerging issue of microplastic contamination, thereby showing a potential regulatory gap in achieving comprehensive water quality management. Given the increasing recognition of microplastics as an environmental and public health concern, the absence of explicit parameters or thresholds for microplastics underscores the need to consider updating the NDWQS. Addressing this gap would enhance the framework for monitoring and managing microplastics in drinking water, contributing to more effective water quality regulation.

Additionally, it is crucial to examine the environmental legal protection for water resources, particularly in relation to microplastic pollution. This analysis addresses whether the current Malaysian environmental law adequately safeguards water resources from microplastic contamination. In Malaysia, the EQA 1974 serves as the principal legislative framework for pollution control and waste management, yet it does not encompass microplastics within its regulatory scope. A comprehensive analysis of the EQA 1974 and its subsidiary regulations reveals that none explicitly address the discharge of microplastics into watercourses. These regulations primarily target traditional pollutants such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), heavy metals, and other conventional contaminants, overlooking microplastics entirely. This omission is significant, as it points to a clear regulatory gap that fails to consider microplastics, an emerging and increasingly recognised environmental threat.

The absence of specific provisions means that industries discharging effluents containing microplastics are not bound by any regulatory requirements to monitor or limit their release into water bodies. Consequently, microplastic pollution remains largely unregulated, posing an escalating risk to Malaysia's water quality and public health. Table 3 provides a detailed summary of the key regulations under the EQA 1974, highlighting each regulation's scope, whether they contain provisions for microplastic discharge, and comments on any omissions related to microplastic regulation.

In addition, WSIA 2006 requires water operators to comply with drinking water quality standards (WSIA 2006, s 41). However, WSIA 2006 itself does not specify the standards but instead relies on the guidelines set by the MOH. According to the Water Safety Plan (WSP) Guidelines developed by *Suruhanjaya Perkhidmatan Air Negara* (SPAN), the MOH's Quality Assurance Program (QAP) under the National Drinking Water Quality Surveillance Programme (NDWQSP) adopts five key

parameters for drinking water regulation: pH, aluminium, E. coli, residual chlorine, and turbidity (SPAN, 2021). The QAP was initiated in response to concerns over water pollution and waterborne diseases. As detailed by Siru (1994), the QAP aims to enhance drinking water quality through the selection of key indicator parameters that monitor compliance across Malaysia. These parameters were chosen based on their ability to detect risks of waterborne diseases and to evaluate the control processes of water treatment. Despite these measures, neither WSIA 2006 nor the QAP includes microplastics as part of their regulatory framework, highlighting a significant omission in addressing microplastic contamination in Malaysia's drinking water standards.

Despite Malaysia's commitment to the United Nations' Sustainable Development Goals (SDGs), particularly Goal Six, which emphasises Clean Water and Sanitation, the absence of specific microplastic regulations reflects a disconnect between policy objectives and regulatory enforcement in water quality management. SDG provides access to safely managed drinking water. This term means that the drinking water quality should be managed properly to ensure it is safe for consumption, which includes being safe from emerging contaminants. As discussed earlier in the introduction, there are signs of progress. The Malaysian Deputy Prime Minister announced that the government is studying the impact of microplastics and other new pollutants on water quality in the country's river basins (Malay Mail, 2024). This initiative represents an important step toward understanding the extent of microplastic pollution and could lead to the development of more comprehensive regulatory measures.

The Role of Institutional Frameworks in Regulating Water Quality

Several institutions are responsible for regulating and monitoring water quality in Malaysia. MOH plays a central role in overseeing the NDWQS and monitors drinking water quality

Table 3: A detailed summary of the key regulations under the Environmental Quality Act (1974)

Regulation Name	Description	Provision for Microplastic Discharge	Comments on Omissions
Environmental Quality Act 1974	The main act governing pollution control, including water quality, air quality, and waste management in Malaysia.	No explicit provision on microplastic discharge.	EQA 1974 does not specifically mention microplastics as a pollutant. This is likely due to the age of the Act, as microplastic pollution has gained significant attention only in recent years.
Environmental Quality (Sewage and Industrial Effluents) Regulations 1979	Regulates the discharge of sewage and industrial effluents into watercourses.	No specific provision on microplastic discharge.	The regulation focuses on more conventional pollutants such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), suspended solids, and heavy metals. Microplastics are not addressed.
Environmental Quality (Scheduled Wastes) Regulations 2005	Addresses the handling and disposal of hazardous waste materials.	No mention of microplastics as a scheduled waste.	Microplastics do not fall under the categories of scheduled wastes defined in this regulation. This indicates a regulatory gap in recognising microplastics as a form of hazardous waste.
Environmental Quality (Industrial Effluent) Regulations 2009	Regulates the treatment and discharge of industrial effluents.	No explicit mention of microplastic discharge.	Like other regulations, this one focuses on conventional water pollutants, overlooking microplastics. The lack of consideration for emerging contaminants highlights an omission.
Environmental Quality (Clean Air) Regulations 2014	Primarily focuses on air pollution control but may indirectly impact water quality through deposition.	No direct provision on microplastics in watercourses.	While this regulation addresses particulate matter, it does not cover microplastics, reflecting an omission in addressing this pollutant.
Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009	Regulates pollution from solid waste transfer stations and landfills, including leachate management.	No direct mention of microplastic discharge.	Although addressing solid waste, this regulation does not specifically address microplastic contamination from landfill leachate into watercourses.
Environmental Quality (Marine Pollution) Regulations 2012	Regulates marine pollution from land-based sources.	No explicit provision on microplastic discharge.	The regulation mainly focuses on oil spills, hazardous substances, and waste dumping. Microplastics are not recognised, which reflects a regulatory gap.

across the country (KKM, 2004). However, the MOH's mandate does not specifically include microplastics, limiting its ability to enforce regulations for this emerging pollutant.

The Department of Environment (DOE) is tasked with regulating pollution control and monitoring industrial effluents, but it also currently lacks specific mandates on microplastic pollution (EQA 1974, s3). As a result, industries releasing microplastics into water sources are not held accountable for their contributions to pollution. The SPAN supervises water service providers and monitors compliance with water treatment standards (SPAN Act, s15), but like MOH and DOE, it operates without a formal framework for addressing microplastics.

At the state level, various water regulatory agencies also manage water resources such as the State Water Authority (*Lembaga Urus Air Selangor*, *Lembaga Sumber Air Negeri Kedah*, and *Badan Kawal Selia Air*) and the Department of Irrigation and Drainage (DID) reflecting Malaysia's federal structure. However, the enforcement and monitoring practices vary significantly between states, leading to inconsistencies in how microplastics are managed across the country. The lack of standardised guidelines and a unified approach across different jurisdictions further worsens the challenge of effectively regulating microplastics in Malaysia's water supply.

One of the most significant challenges faced by these institutions is the absence of microplastic-specific regulations. Without explicit standards, agencies like MOH, DOE, and SPAN do not have the legal authority to enforce monitoring or treatment requirements, resulting in a fragmented and inconsistent approach to managing microplastic pollution. Another main challenge is the limited technical capacity and resources available to water treatment plants, many of which lack the advanced technologies needed to remove microplastics effectively. This technical gap means that even if microplastic standards were established, the capacity to monitor and enforce them would be limited.

Coordination and data sharing among different institutions are also inadequate, making it difficult to implement a cohesive strategy for addressing microplastic pollution. Without a centralised mechanism for collecting and disseminating data on microplastic contamination, agencies are unable to make informed decisions or develop comprehensive policies.

Potential Impact of Implementing Microplastic Regulation

The implementation of microplastic filtration technology in Malaysia's water treatment systems is expected to greatly influence both the operational processes and the resulting water tariffs for consumers. Based on the earlier discussion, the integration of advanced filtration methods such as membrane filtration, nanofiltration, or advanced oxidation processes will bring significant improvements to the water treatment landscape by enhancing drinking water quality. However, it will also exert financial pressure on the water sector, which is already facing challenges due to low revenue generation by water operators. This is primarily because the current low tariffs do not allow operators to achieve full cost recovery.

One of the most immediate requirements for complying with microplastic regulations will be the need to overhaul the existing treatment infrastructure. Malaysia's water treatment facilities predominantly rely on conventional methods (Chan, 2018) such as coagulation, sedimentation, and basic filtration, which are largely ineffective in removing microplastics (Osman *et al.*, 2023; Radityaningrum *et al.*, 2023), particularly those smaller than 10 micrometres.

Shifting to advanced technologies like membrane bioreactors or nanofiltration requires huge capital investment, not only for the installation of new systems but also for retrofitting older plants to handle the new technology. With the new Malaysia tariff setting mechanism that incorporates both

operational and capital expenditures into the water tariff structure (Free Malaysia Today, 2024), these costs will undoubtedly be passed on to consumers in the form of increased water tariffs. This will result in increased operational costs of water services. Financial and logistical challenges already constrain water operators, they will find it difficult to absorb the additional cost for investment without adjusting tariffs accordingly.

Moreover, the ongoing maintenance and operational costs associated with these technologies are significant. Advanced filtration systems, particularly those that handle microplastics, require frequent monitoring, maintenance, and energy input. For example, membrane filtration systems are prone to fouling, which can increase both the energy requirements and the need for frequent cleaning or membrane replacement. The added operational complexity in handling these advanced systems means that water operators will incur higher costs in terms of energy consumption, technical staff, and equipment maintenance. Malaysia's energy prices, which can be volatile add a layer of financial strain to this scenario, as water treatment plants are already substantial energy consumers. These factors combined will inevitably lead to higher tariffs for treated water, as operators must recoup the additional costs through consumer pricing.

The regulatory environment will also play a role in shaping the financial impact. Currently, Malaysia's water quality standards do not specifically address microplastics and monitoring is not yet a mandated practice. However, once microplastic limits are incorporated into the NSDWQ, water operators will face the added burden of regulatory compliance, including the need to monitor microplastic levels continuously. The monitoring technologies required such as micro-Fourier Transform Infrared Spectroscopy (μ -FT-IR) and Micro-Raman Spectroscopy are costly and require highly specialised technical knowledge to operate effectively. These systems are not only expensive to install but also require regular calibration and upkeep, further driving

up the cost of water treatment operations. The need for such high-tech solutions will significantly alter the operational dynamics of Malaysia's water treatment plants, which, in turn, will affect water tariffs.

Legal and Regulatory Framework for Microplastic Contamination in ASEAN Countries

The legal and regulatory framework for microplastic contamination in ASEAN countries remains fragmented, with most policies addressing broader plastic waste management rather than microplastics specifically. However, some nations have taken initial steps by integrating microplastic-related measures into their existing environmental and waste management laws. For example, Thailand's Plastic Waste Management Road Map 2018-2030 includes a ban on microbeads in cosmetic products, marking a direct regulatory intervention targeting primary microplastic pollution (Pollution Control Department, 2021).

Similarly, Vietnam's National Action Plan on Marine Plastic Litter Management (2020-2030) commits to banning the production and import of cosmetics containing microbeads by 2025, demonstrating a proactive legislative approach in reducing primary microplastic sources (Government of Vietnam, 2019; Collard, 2024). Despite these advancements, ASEAN lacks a unified, binding regional agreement that mandates member states to implement comprehensive microplastic pollution controls, leading to inconsistencies in enforcement and effectiveness across the region.

Beyond specific bans on microbeads, broader policies addressing marine debris and plastic waste help mitigate microplastic pollution. Indonesia's Presidential Regulation No. 83/2018 on Marine Debris Management aims to reduce marine plastic debris by 70% by 2025, supporting research and innovation to address microplastic contamination as part of a larger marine waste management strategy (Collard, 2024). Similarly, the Philippines' Extended Producer Responsibility (EPR) Act

of 2022 mandates large corporations to recover a percentage of their plastic packaging waste, fostering a circular economy approach that could reduce secondary microplastic pollution over time (Collard, 2024). Singapore's Zero Waste Masterplan (2019) while not explicitly focused on microplastics, prioritises the reduction of plastic waste sent to landfills, indirectly limiting microplastic release into the environment (National Environment Agency (NEA), 2021; Collard, 2024). While these policies create a foundation for addressing plastic pollution, the lack of microplastic-specific monitoring and enforcement mechanisms remains a significant regulatory gap.

To enhance the effectiveness of existing legal frameworks, ASEAN countries must adopt a more targeted regulatory approach that includes standardised microplastic monitoring, stricter enforcement mechanisms, and enhanced regional coordination. Existing efforts such as Thailand's upcoming ban on plastic waste imports in 2025, reflect growing recognition of the need for stronger pollution controls, but without microplastic-specific provisions, these measures remain insufficient to tackle the full scope of the issue (The Guardian, 2025).

Strengthening national laws by incorporating microplastic thresholds in water quality regulations, enforcing stricter industrial discharge standards, and expanding producer responsibility beyond microplastics to include other plastic waste are critical next steps. Additionally, ASEAN member states could benefit from aligning their policies with global regulatory standards such as the Basel Convention and Stockholm Convention, ensuring comprehensive and enforceable measures to combat microplastic contamination at both national and regional levels.

Conclusions

The infiltration of microplastics into Malaysia's drinking water supply presents a pressing environmental and public health challenge, exacerbated by rapid industrialisation and inadequate regulatory oversight. Despite

mounting evidence of microplastic contamination across surface water, sediments, and even treated drinking water, Malaysia's current legal and institutional frameworks remain ill-equipped to address this emerging threat. Existing water quality regulations, including the National Drinking Water Quality Standards (NDWQS), the Environmental Quality Act 1974, and the Water Services Industry Act 2006 lack specific provisions for microplastics, leaving a significant regulatory gap.

Furthermore, Malaysia lags behind global and regional efforts to integrate microplastic monitoring into water governance, which compromises public health protection and environmental sustainability. Without explicit microplastic standards and enhanced water treatment capabilities, the country risks prolonged exposure to these contaminants. Addressing microplastic pollution requires a comprehensive regulatory response that aligns with international best practices, strengthens enforcement mechanisms, and ensures Malaysia's commitment to safe and clean drinking water for all.

Recommendations

In order to effectively regulate microplastic contamination in drinking water, Malaysia must strengthen its regulatory framework by adopting a proactive approach grounded in the public trust doctrine and the precautionary principle. The public trust doctrine, which positions the government as a steward of natural resources emphasises the state's duty to protect water resources for current and future generations. In this context, water supply is not just an economic commodity but a public resource that must be preserved and safeguarded against emerging threats such as microplastic contamination. The precautionary principle complements this by advocating for preventive action, even in the absence of full scientific certainty about potential harm. While research on the effects of microplastics is still emerging, the principle calls for early intervention to

avoid irreversible environmental and public health damage. If Malaysia waits for conclusive evidence on microplastic toxicity, it risks long-term degradation of its water systems. Applying the precautionary principle enables Malaysia to take pre-emptive action in protecting its water resources. This approach ensures the country fulfils its obligation under the public trust doctrine, maintaining the safety and accessibility of its water supply for the public.

A key part of this proactive regulatory framework involves developing specific standards for microplastic contamination in drinking water. Malaysia's National Drinking Water Quality Standards (NDWQS) should be updated to include quantifiable thresholds for microplastics, drawing inspiration from international regulations like the European Union's Drinking Water Directive. These standards will serve as a legal and operational framework for monitoring and controlling microplastic levels, ensuring that the public trust obligation to protect water quality is met. Setting clear thresholds for microplastic content allows the regulatory framework to embody the precautionary principle. This approach acknowledges the uncertainty surrounding microplastics and errs on the side of caution to prevent potential health risks. This ensures that water governance is both legally sound under the public trust doctrine and scientifically forward-thinking, recognising the necessity of early intervention in managing emerging contaminants.

In line with new regulatory standards, Malaysia must invest in comprehensive monitoring systems and cutting-edge filtration technologies to effectively address microplastic contamination. Traditional water treatment methods are inadequate for removing microplastics, particularly those smaller than 10 micrometres. Technologies such as membrane bioreactors, nanofiltration, and micro-Fourier Transform Infrared Spectroscopy (μ -FT-IR) must be integrated into the country's water treatment infrastructure. This investment reflects the public trust doctrine's call for the state to

manage water resources responsibly, ensuring long-term sustainability and public access to safe water. Implementing these technologies is not merely an operational upgrade but a legal and ethical obligation under the state's trust responsibilities. While these upgrades entail financial costs, they are essential to safeguarding public health, aligning with the precautionary principle's focus on preventing harm before it becomes irreversible.

Adopting the precautionary principle as the cornerstone of Malaysia's regulatory approach to emerging contaminants like microplastics will enable the country to act pre-emptively, mitigating risks before they fully materialise. This principle is particularly suited in addressing scientific uncertainty around emerging pollutants. By embedding the precautionary principle into water governance, Malaysia can proactively manage risks, preventing microplastic accumulation in water systems that could otherwise have detrimental, long-term health, and environmental consequences. This early action framework not only protects public health but also positions Malaysia as a global leader in innovative water regulation, demonstrating that environmental governance must evolve with emerging scientific knowledge. Integrating precautionary measures into regulatory strategies positions Malaysia to help establish a global standard for managing contaminants in water supplies, especially in cases where scientific certainty regarding their impacts is lacking.

Besides, effective regulation also requires collaboration across sectors and robust public engagement. The public trust doctrine underscores the necessity of involving the public in environmental stewardship, as citizens are both beneficiaries and stakeholders of the country's water resources. Educational campaigns informing citizens about the dangers of microplastics and promoting plastic waste reduction will increase public pressure for stronger regulatory measures, fostering a culture of accountability in water governance. Collaboration between

government agencies, research institutions, and industries will streamline the implementation of new regulations and facilitate knowledge-sharing. As Malaysia enhances its regulatory framework, these partnerships will ensure that the latest scientific advancements in microplastic filtration and detection are applied effectively. Such collaboration reflects both the public trust doctrine's participatory nature and the precautionary principle's call for interdisciplinary approaches to environmental challenges. Globally, these efforts will bolster Malaysia's leadership in combating microplastic contamination, setting an example for other nations to follow.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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