JMarPT
Journal of Marine Problems and Threats
JMarPT 1(1): 44–65
ISSN 3048-037X

Institute for Advanced Science, Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

Prevention of decreasing river water quality due to anthropogenic activities: A systematic review of water pollution on Cisadane River

MUHAMMAD NABIL MAKARIM[1]*
[1] *School of Environmental Science, University of Indonesia, Jalan Salemba Raya, Jakarta, Indonesia;*
*Correspondence: muhammad.nabil28@ui.ac.id

Received Date: December 1, 2023 Revised Date: January 25, 2024 Accepted Date: February 19, 2024

ABSTRACT
The Cisadane River, which flows through the provinces of West Java and Banten, is severely contaminated as a result of numerous human activities, unregulated dumping of industrial and domestic waste, and growing urbanization and poor management. An important part of West Java's and Banten's overall river system is the Cisadane River Basin. An overview of the general state of Indonesia's rivers and the prevalent pollution, especially in the Cisadane River ecosystem, is provided in this review. The method used is a systematic literature review. Literature review involves collecting references from various books, documents, archives, and others related to the research focus. The data collection method in this study uses the systematic literature review (SLR) method. This review provides insights into the environmental conditions of the Cisadane River and general river conditions in Indonesia, as well as the pollution of pollutants that commonly occur in Indonesia. In summary, this review offers several important contributions by (a) identifying and discussing the characteristics of the Cisadane River and the general picture of rivers in Indonesia, (b) identifying and discussing pollutant pollution in detail from water quality parameters in relation to its physicochemical properties and its impact on water sources and usage, (c) identifying and discussing river water pollution control in Indonesia, focusing on the policies of applicable legal products, and finally, (d) suggesting directions for future research. Based on this review, policymakers can be influenced to develop sustainable strategies in preventing the decline in river water quality due to anthropogenic activities.

KEYWORDS: anthropogenic; Cisadane river; pollution; water quality control

1. Introduction

The concept of sustainability has become a crucial focus for policymakers and decision-makers in water and environmental management. Since the Brundtland report in 1987 (WCED, 1987), the idea of sustainability has been more widely accepted as a helpful framework for tackling a range of difficult problems at the governance and socioeconomic system scales. The reason for this is the wide range of interpretations surrounding the phrase "sustainability." The US Environmental Protection Agency (EPA) defines sustainability as "to create and maintain conditions that allow humans and nature to live in productive harmony, fulfilling the social, economic, and other needs of present and future generations" (Shafiei et al., 2022).

As they carry up to 260 Tg of dissolved organic carbon (DOC) and 200 Tg of particulate organic carbon (POC) annually into the sea, rivers are essential for bridging

Cite This Article:
Makarim. (2024). Prevention of decreasing river water quality due to anthropogenic activities: A systematic review of water pollution on Cisadane River. *Journal of Marine Problems and Threats,* 1(1), 44-65. https://doi.org/10.61511/jmarpt.v1i1.2024.650

land and marine ecosystems. However, significant human and climatic changes are presently occurring in river ecosystems, which may result in increasing CO2 emissions, fragmentation, and nutrient loading. Numerous variables, including temperature, sunshine, rainfall, land use, and human activity, can cause these variations. It is difficult and hard to understand how these elements affect the dynamics of organic carbon in river systems. Thus, limiting or avoiding their negative consequences and advancing sustainable development require recognizing the major causes of climate change and human influences on river systems (Li et al., 2023). Human activity has the potential to significantly modify regional runoff and impact the effectiveness of water resource usage, particularly when it comes to land-use changes like agriculture, deforestation, and grassland conversion. The dynamics of runoff resulting from climatic variability and heavy human activity must be understood in order to manage water resources sustainably and preserve the stability of local ecosystems. The geographical variations in climatic conditions and the intensity of human activity that result in runoff heterogeneity are evidence that concern over the effects of climate change and human activity on runoff dynamics has grown recently (Sonthiphand et al., 2023).

Within their sphere of influence, river catchment regions' water quality plays a critical role in maintaining both micro- and macro-ecosystems. The health of river systems has a direct impact on their capacity to sustain life. Anthropogenic pressure on surface water rises with an increasing human footprint on Earth, which causes a degradation in water quality within water systems (Mahabeer & Tekere, 2021). Freshwater is a resource that serves several purposes for people. It can be contaminated, extracted, diverted, stored, or used in other ways, all of which might reduce its value as a home for other creatures that share it (Dudgeon et al., 2006). Since humans rely on freshwater from river sources for a variety of uses, it is essential to locate pollution sources in order to stop and manage more contamination. Water quality assessment is a widely used method to assess the health of water ecosystems and their effects on human and environmental health. It involves a variety of physico-chemical parameters and biological indicators of a water body, taking into consideration its natural state, anthropogenic influences, and usage (Mahabeer & Tekere, 2021).

Introduced by the World Health Organization (WHO) in 2004, the Water Safety Plan (WSP) strategy is being more widely utilized globally to guarantee clean water for human use and is now required by recommendations. From extraction to consumption, every link in the water supply chain is thoroughly risk-assessed as part of the WSP strategy (Zanotti et al., 2022). Large rivers need more frequent and extended sample periods in order to detect non-point source contamination, which might produce data with significant temporal and geographical fluctuations. Variability may cause data sets from densely populated regions to overlap upstream and downstream, creating the false appearance that urban areas have little effect on water quality (Engloner et al., 2023). Rivers may be exposed to anthropogenic pollution in a variety of ways, at varying degrees of detection, and in varied volumes. Point sources of pollution, like untreated wastewater, are easy to spot because they change the ecosystem by adding chemicals that make the water more electrically conducting, alkaline, and high in heavy metals and trace elements, among other things (Engloner et al., 2023).

Among the common pollutants found in water, dyes and heavy metals hold a significant position. Generally speaking, they come from industrial processes including mining, electroplating, metal smelting, tanning, textile and dye manufacture, fertilizer and pesticide manufacturing, papermaking, and the paint industry. One of the main causes of environmental issues is the unpermitted dumping of heavy metals and dyes, which has significant health and environmental dangers (Slama et al., 2021). Additionally, volatile organic compounds, or VOCs, released by industrial processes like dyeing that produce organic contaminants pose a threat to the environment. Dyes include quickly-evaporating organic components. Nonpolar organic solvents, also referred to as volatile materials or solvents, produce VOCs when they have a vapor pressure of at least 20 °C or 0.01 kPa (Jiménez-López & Hincapié-Llanos, 2022). VOCs have an adverse effect on the environment and climate change, and they are significant precursors of secondary aerosol formation and tropospheric ozone (Liu & Zheng, 2020). They also pose a concern for human health. Major contributors to the creation of ozone include solvents including acetone, butene, butadiene, m/p-xylene, and toluene (Liu & Zheng, 2020).

In order to preserve the healthy micro- and macro-ecosystems under their impact, river catchment regions' water quality is essential. A river system's intrinsic health state has a direct bearing on its capacity to sustain life. As a result of increased anthropogenic pressure on surface water brought on by human activity over time, aquatic systems' water quality has declined (Mahabeer & Tekere, 2021). One of Indonesia's 15 priority river basins is the Cisadane River Basin, according to the country's National Medium-Term Development Plan 2014–2019. One of the main rivers in the Cisadane River Basin and a symbol of Tangerang's status as a Water Front City is the Cisadane River. In addition, the Cisadane River serves as the main source of raw water for the Regional Drinking Water Company (PDAM), which uses it to supply clean water to Tangerang city and district as well as the Soekarno-Hatta International Airport. One of Jakarta's satellite cities, Tangerang, has grown rapidly, which has contributed to the corporate and industrial sectors' notable expansion. The need for land for housing developments has also increased due to the expanding population. Rapid urbanization and population expansion will alter land usage, which might have unfavorable effects like increased pollution levels. The quality of river water declines more quickly with increasing land use changes (Namara et al., 2020).

Every year, Tangerang's industrial density has increased, especially in the area surrounding the Cisadane River Basin. As to Namara et al. (2020), the Tangerang City Central Statistics Agency (BPS) reports that the count of industries was 510 in 2010, surged to 641 in 2013, and then soared to 699 in 2016. The Cisadane River is essential to the operations of many of the city's enterprises. Regretfully, the Cisadane River's water quality has declined dramatically in recent years (Rarasati & Fadhila, 2017). In order to improve water quality and river ecosystems in Indonesia, particularly the Cisadane River, the goals of this paper are to (1) give a broad overview of current knowledge on Indonesian river ecosystems and water pollution and (2) establish future guidelines for research and preventive measures. After gathering and analyzing the literature, the researchers categorized the studies according to the four pollutants that have been examined the most: (1) nutrients; (2) heavy metals; (3) organic pollutants; and (4) plastic/microplastic studies. This study's scope is restricted to the following: (a) studies that measure the chemical and microbiological contaminants that result from human activity; (b) studies that evaluate the effects of anthropogenic contaminants on the environment and human health rather than their social or economic effects; (c) studies that measure the pollutants, river basins, and sediments; and (d) research that is written in both Indonesian and English. In order to better understand Indonesian river catchment waters and to help local academics and government agencies enhance water quality and ecosystem health, the researchers talk about upcoming challenges and possibilities.

2. Methods

The Cisadane River served as the site of the research. The study started by examining the predominant anthropogenic water pollution agents and pollution variables in rivers that are similar to the Cisadane River worldwide. After that, a literature study that may be applied to the Cisadane River was used to analyze strategies for stopping the deterioration in river water quality.

This study employed a qualitative case study technique that included a review of the literature and data collection. For the literature review, information about the study topic was gathered from a variety of sources, including books, papers, archives, etc. By performing literature reviews with study subjects to gain the necessary information, the author hoped to collect the correct data. The systematic literature review (SLR) approach was employed in this study's data collection process.

This article is organized in accordance with the specified reporting item standards for systematic reviews and meta-analyses on assessments of this kind and is based on a systematic analysis of the scientific literature that is currently accessible addressing the situation of water pollution worldwide. These kinds of activities help to summarize scientific advancements and point out knowledge gaps that need to be addressed by the scientific community, environmental managers, and policymakers. Using the following keywords: anthropogenic AND pollution AND water AND river, along with article titles, abstracts, and keywords in the article titles, the first search for scientific literature was carried out on ScienceDirect and a number of international journals. Peer-reviewed books, research articles, and book chapters that were released in both English and Indonesian between 2000 and 2023 were taken into consideration for this review. The first assessment of abstracts and titles, as well as any literature specifically mentioning problems of pollution brought on by human activity, served as the foundation for the selection of scientific material on ScienceDirect. In addition, all relevant references from documents found through topic-based searches and other studies on pollution caused by human activities were looked over to provide a conceptual framework and examples of pollution in other settings that could be used to compare with rivers. Following the selection of certain studies, comprehensive data, including full citations, evaluated rivers, and their attributes, were taken out of each selected document. Additionally, data on microorganisms connected to anthropogenic activities as well as organic and inorganic pollutants were retrieved.

Data were meticulously gathered from the primary text, tables, and supplementary materials in the majority of the examined publications. These numbers provided approximated values that were used in other research to provide data on the anthropogenic activity-related reduction in water quality. In the research area and discussion (or findings and discussion) part of the examined studies, the possible pollution resulting from anthropogenic activities was recognized. The authors then discussed and connected this pollution to human activities in the larger study region. The introduction, discussion, and conclusion parts of the examined publications emphasized the key problems and directions for future studies on pollution caused by anthropogenic activities. In considering this environmental issue as a "major problem," the researcher took into account factors that might help develop understanding about pollution caused by anthropogenic activity in rivers and river conservation. This was meant to serve as a research challenge, rationale, and set of suggestions for future work. Data on the state of the water quality was gathered from government information sites and other online information sources.

3. Results and Discussion

3.1 River water pollution in Indonesia

In Indonesia, river pollution is a major problem. According to information from the Ministry of Environment and Forestry, 73.24% of the 140 rivers spread over 34 provinces in 2016 were classified as contaminated. Merely 2.01% of the rivers satisfied the class 2 water quality requirement. Firmansyah et al. (2021), list 15 priority river basins that need to be restored as part of the National Medium-Term Development Plan (RPJMN) 2014–2019. These river basins include West Nusa Tenggara (DAS Moyo), Kalimantan (DAS Kapuas), Sulawesi (DAS Jeneberang, Saddang), Java (DAS Citarum, Ciliwung, Cisandane, Serayu, Solo, Brantas), and Sumatra (DAS Asahan Toba, Siak, Musi, Way Sekampung, and Way Seputih). The Ministry of Environment's Regulation Number 1 of 2010 on the execution of environmental pollution control calls for the execution of initiatives like the

Clean River Program; however, the outcomes haven't been ideal. According to a study from the Data and Information Center of the Republic of Indonesia's Ministry of Environment, this is consistent with the trend of the country's water quality index declining between 2013 and 2017. According to a 2019 study by Hendra Andiananta Pradana on the Water Quality Identification and Pollution Load of the Bedadung River in the Intake of the Water Treatment Plant of the Jember District Water Company, the Bedadung River is one of the most polluted rivers in Indonesia. According to the research, the IPA Tegal Gede and IPA Tegal Besar intakes have Class I and Class III water quality, respectively. Class III COD values were seen at the IPA Tegal Besar intake. Between the two intakes, there was a noticeable difference in the average pollutant loads at IPA Tegal Gede and Tegal Besar, which were 24.96 kg/day and 74.03 kg/day, respectively. In a different study, the amount of E. coli bacteria in the Karang Mumus River and the number of toddlers in the Bandara sub-district of Samarinda who had diarrhea were linked to how waste, feces, and home waste were managed (Firmansyah et al., 2021).

Furthermore, there is an additional incident concerning the Krukut River, which is one of the principal rivers inside the capital region. According to DKI Jakarta Gubernatorial Regulation No. 582/1995, this river is categorized as raw drinking water and is administered in collaboration with PT. PAM Jaya. It is crucial to the continuation of neighborhood activities in the capital. The quality of the water in the Krukut River is declining as more people migrate into DKI Jakarta. People participate in a range of industrial, residential, and agricultural activities that produce waste and degrade river water quality in order to fulfill their daily needs. The amount of garbage people produce, particularly the liquid waste they frequently dump into waterways, contributes to Jakarta's declining environmental quality and carrying capacity. The reason for this drop in river water quality might be the increasing volume of trash, both from industrial and household sources, that is entering the river body (Rachmawati et al., 2020). Even with relevant legislative requirements in place, the river's water quality is still declining, which suggests that policies are not being implemented effectively. As a result, additional actions are required to support current policies.

3.2 Pollution in the Cisadane River

One of the principal rivers in the Indonesian provinces of Banten and West Java is the Cisadane River. Its watershed spans a distance of around 140 km and has a total size of about 1,375.43 km2. This river's source is in the Bogor Regency's Mount Salak, also known as Mount Pangrango (Purwati et al., 2019). The Cisadane River is subject to disturbances as a result of continuous industrialization, urbanization, and agricultural activity in the regions surrounding it, as is often the case with large rivers. The main cause of the contamination in the rivers is human activity. The Cisadane River is an essential supply of raw water for the towns of Tangerang Region and Bogor City. This important river flows through numerous administrative districts, including Tangerang City and Bogor Regency, where there is a high level of urban activity and therefore high pollution levels (Purwati et al., 2019). One of the most important parts of the entire system is the Cisadane River Basin. This is a result of land use changes in the upper Cisadane River Basin, which have an effect on areas downstream. Any changes in the upper region will have an impact on the downstream region. Tangerang Regency and Tangerang City are the two territories that make up the Cisadane River Basin's downstream. Numerous businesses that are situated near the Cisadane River discharge their trash into it without properly treating it (Aisyah, 2014).

3.3 Heavy metal pollution

While surface runoff happens during the rainy season, rivers carry and absorb pollutants from industrial and urban effluents (Singh et al., 2005). Heavy metal pollution is a major contributor to the overall cycle and biomagnification processes as a result of anthropogenic activity. Even in low quantities, heavy metals are very hazardous (Long et al., 2021). Heavy metals are known to provide major health concerns to people in a variety of states and at varying quantities in the environment. When compared to other sources, industrial wastewater is the primary source of heavy metal pollution. Industrial waste buildup and atmospheric metal sedimentation are the next two main sources of pollution in the soil. Sustainable industrial expansion is the cause of the buildup of heavy metals in drinking water and the illnesses that result from it. Heavy metals like Ba (hypertension), B (anxiety and gastrointestinal problems), Al (neurotoxin), Pb (delayed mental and physical development in children and kidney and blood pressure issues in adults), Cr (allergic dermatitis, liver damage, and vomiting), Mn (neurotoxin), Fe (abdominal pain, vomiting, and skin irritation), Co (pneumonia and asthma), Ni (skin diseases, cancer, and immune, neuro-, and genotoxicity), Cu (digestive disorders and liver or kidney damage), Zn (fatigue and dizziness), and Cd (carcinogenic, endocrine disruptor, kidney damage, and osteoporosis) are among the heavy metals that are linked to water sources (Raj et al., 2023).

Anthropogenic activities such as solid waste dumping on riverbanks, wastewater treatment plant maintenance, and wastewater discharge from industrial sites are the major causes of river pollution. One river that has high metal contamination is the Cooum River in the well-known South Indian city of Chennai. Twelve elements (Ba, B, and Al) and heavy metals (Pb, Cr, Mn, Fe, Co, Ni, Cu, Zn, and Cd) were measured in water samples taken from 27 sites. According to Raj et al. (2023), the samples had concentrations of these components that were higher than those that the World Health Organization recommended. According to the research by Amal Raj et al., employing algae to absorb heavy metals is a successful remediation strategy for water contamination, meaning that the technique will soon be able to be used extensively. Algal remediation is seen as a practical, affordable, and eco-friendly way to rid the water of contaminants. Using algae to remove industrial pollutants or extract valuable products from wastewater, phytoremediation is an eco-friendly procedure (Deshmukh et al., 2019).

Over the course of 19 sample stations throughout Patagonia's 4400 km coastline, the quantities of five heavy metals (mercury, cadmium, copper, lead, and zinc) in marine sediments were examined. Comodoro Rivadavia and San Antonio Oeste had the highest amounts, indicating anthropogenic contamination. The primary source of heavy metal contamination from abandoned mining operations that began before 1970 is mine tailings, namely lead and zinc. After mineral products are extracted from ore-containing rocks, debris known as mine tailings is left behind. In addition to crushed rocks, the tailings include potentially hazardous materials, including heavy metals and residual chemicals. Because tailings are kept on the ground close to San Antonio Bay, the region 10 km around the site is also affected by pollution. High concentrations of lead and zinc, particularly in the intertidal zone, have been found in sediments and marine biota along the San Antonio Bay channel as a result of metal leakage. Lead and zinc contamination still impacts the bottom surrounding the polluted site, even though metal mining has stopped in the coastal area and there are no new tailing mining operations (Häder et al., 2020).

With a total length of 5464 km and a basin area of 79500 km2, the Yellow River is the sixth-longest river in the world and the second-longest river in China. The Yellow River, sometimes referred to as China's mother river and the site of the country's civilization, provides water to 15% of the country's agricultural land and supports around 12% of its people (Chen et al., 2020; Miao et al., 2010). However, extensive anthropogenic activities along the Yellow River's main course have resulted in the discharge of significant amounts of pollutants, which have severely contaminated the river and caused high concentrations of heavy metals in certain locations (Miao et al., 2010; Zhang et al., 2020; Zhang et al., 2020). Particularly, there are significant ecological hazards associated with Hg, Pb, and Cd in the upper Yellow River (Fan et al., 2008; Liu & Liu, 2013), The most strict water resources management system (SWRMS) was put into place in 2013 in order to reduce water damage and enhance the biological environment of the Yellow River (Xie et al., 2022).

3.4 Sediment buildup

As a holding pond, sediment acts as an indication of environmental pollution in the form of pertinent metal contamination (Williams & Antoine, 2020). Rivers may serve as heavy metal reservoirs in addition to serving as surface water resources for a variety of uses, including tourism, fishing, agriculture, industry, and a container for domestic waste. Runoff and waste materials can introduce heavy metals into waterways. Natural mechanisms, such as climatic and geological processes like rock weathering, can also allow them to penetrate aquatic habitats (Looi et al., 2019). Because there isn't enough hydrodynamic exposure to move the heavy metals elsewhere, in these situations, the metals usually collect in the sediment and stay in the reservoir for a longer period of time (Varol, 2020). Hydrodynamic processes in rivers have the ability to move silt downstream or build up in the sediment of the riverbed.

A significant amount of heavy metals has entered rivers as a result of rapid industrialization and urbanization, lowering water quality and harming ecosystems (Xiao et al., 2021). Because of their biotoxicity and enduring presence in the environment, heavy metal buildup also presents a risk to human health (Ali et al., 2022). Human toxicity may arise from consuming high concentrations of heavy metals in water and other media (Lin et al., 2021). Diabetes, anemia, and cancer can result from long-term exposure to certain metals (Hoang et al., 2021). Furthermore, heavy metal buildup can exacerbate ecological toxicity and modify the chemical, physical, and nutritional characteristics of water (Zhao et al., 2021).

Urbanization and changing land use pose a serious danger to Yogyakarta, Indonesia's Winongo River. The watershed of the river is split into three zones: the city is located in the middle stream region, where there is predominantly residential and agricultural land; the downstream area is primarily made up of suburban and agricultural land. High-intensity human activities along the Winongo River, particularly household and industrial operations (Yang et al., 2020), frequently dump gray water into the river directly, typically without the use of wastewater treatment facilities (WWTP). Untreated river waste, particularly in the form of heavy metals, has drawn a lot of attention because the majority of Yogyakarta province's residents use the river for daily activities as well as for agriculture and fishing (Li et al., 2021). Iron (Fe), chromium (Cr), calcium (Ca), and cadmium (Cd) are all present in graywater from washing operations. The most prevalent and dangerous heavy metals for human health are lead (Pb), chrome (Cr), and cadmium (Cd), which may be lethal in even minute doses. These metals are commonly found in mechanical workshops, the metal industry, and automobile emissions (Lin et al., 2021). Fertilized soil that has been supplied with nitrogen (N), phosphorus (P), and potassium (K) has high concentrations of Fe, Pb, Cd, and Cr. Typically, bedrock contains iron (Fe) and aluminum (Al), as their primary constituent is volcaniclastic silt derived from younger Merapi deposits. In the Winongo watershed, six metals—Al, Fe, Pb, Cr, Cd, and copper (Cu)—have correlations with heavy metals from every form of land use (Fadlillah et al., 2023).

It is crucial to evaluate ecological concerns since heavy metals from soil and other surface areas can be readily transported by runoff and absorbed in water (Duodu et al., 2016). For the purpose of monitoring, these assessments enable a thorough grasp of the concentration of heavy metals in river water and sediment (Hoang et al., 2020). Nevertheless, little is known about the concentration and geographic distribution of heavy metals, and there is a dearth of relevant studies on the ecological risk assessment of the Winongo River. Thus, the purpose of this study is to: (1) locate potential heavy metal sources in the Winongo River; and (2) show the spatial distribution and concentrations of heavy metals in close proximity to the main land uses along the river, such as agriculture, fishing, local activities, industry, metal fabrication, and the identified motorbike and car workshops. (2) To assess heavy metal exposure in the Winongo River, compute the Enrichment Factor (EF), Geographical Accumulation Index (Igeo), Ecological Risk Index (Er), and Potential Ecological Risk Index for Pb, Cd, Cr, Fe, Al, and Cu (Fadlillah et al., 2023).

3.5 Microplastic pollution

Plastic items experience mechanical wear, UV radiation exposure, natural weathering, and a variety of biological reactions throughout everyday usage, which results in the development of many secondary microplastics that cannot be avoided. Different plastic kinds age differently due to different circumstances. For instance, it was shown that they degraded more readily to generate microplastic particles under the same natural circumstances as polyethylene (PE), polypropylene (PP), and polystyrene (PS) (Li et al., 2022). The surface of microplastics can also change due to weathering and aging, and newly created holes and fissures serve as places where more contaminants can adsorb. You can add more pollutants by changing the surface's charge, hydrophobicity, polarity, potential, surface functional groups, biofilm, charged minerals, and other features. However, heavy metals like Cr (VI) will make it harder for pollutants to stick to the surface because they are electrostatically attracted to it (Bhagat et al., 2021; Duan et al., 2023; Z. Li et al., 2022).

Comparing plastic components to persistent organic pollutants (POPs), they are typically regarded as physiologically inert. Nevertheless, throughout the synthesis process, monomers and unpolymerized impurities will have adsorbed on the plastic surface of these plastics. In order to improve the look and maximize performance, colors and different additives are simultaneously applied to the plastic surface. Substances other than plastic have the potential to affect natural water systems and endanger the health of people, animals, and plants (B. Xu et al., 2018). Once plastic parts seep into the surrounding ecosystem, they will react with other elements in the water body to create new pollution sources. Microplastic aggregates can induce cytotoxicity, oxidative stress, and inflammatory reactions in living things (Jenner et al., 2022; Kim et al., 2021; Mak et al., 2019). Microplastics from bottles and packaging, such as polypropylene (PP) and polyethylene terephthalate (PET), have been found deep in human blood and lungs thanks to the μFTIR spectrometer detection technique (Jenner et al., 2022).

Aquatic ecosystems include microscopic plastic particles, particularly at lower trophic levels where the amount of microplastics consumed per gram of wet weight is larger than at higher trophic levels. Anthropogenic activities and careless waste disposal, such as dumping waste, effluent discharge, industrial, agricultural, fishing, shipping traffic, and environmental factors, are the main causes of microplastics found in water bodies. These activities have been tracked at remote locations using bioindicators and tracking tools, including life cycle inventories and numerical modeling (Rossatto et al., 2023). In time, aquatic life will either ingest microplastics in rivers or they will become lodged on riverbanks and deposit in sediment. Water currents may also carry them to the sea. The adsorption and desorption of chemicals that have stuck to the surface of microplastics could cause direct contamination because their surface is hydrophobic and they have a lot of surface area. The interactions between heavy metals, different persistent organic pollutants, polycyclic aromatic hydrocarbons, drugs, pesticides, nanoparticles, organic halogens, plastic additives, antibiotics, and organotin, among other environmental pollutants, and microplastics and nanoplastics result in the formation of copolymers. These copolymers have the potential to have additive, antagonistic, and synergistic harmful effects on living things. Different types of copolymers can hurt living things in different ways, depending on how much of the contaminants and plastic parts change in the copolymers. However, in the water, phytoplankton, microplastics, and microbes will all come together to form heterogeneous aggregates that will be harmful to creatures when consumed (Bhagat et al., 2021; Stapleton et al., 2023; P. Xu et al., 2018). For instance, fish toxicity is increased when herbivorous fish consume heteroaggregates (Ding et al., 2022).

It has been shown that microplastics may build new kinds of complex plastic-rock materials by combining with rocks in addition to biological matter (Wang et al., 2023). Plastispheres are formed when individual microplastics combine with surface microorganisms to form a biofilm. The eco-corona is a mixture of protein and organic materials that envelops nanoplastics (Shi et al., 2023).

Researchers evaluated seven regions: Africa, the Middle East, China, East Asia, Oceania, Europe and Central Asia, India, and South Asia. They discovered that the sources of microplastics are tires, city dust, marine coatings, personal care products, plastic granules that travel through roads, wastewater, and oceans, and road markings applied during infrastructure development and maintenance (paint, thermoplastics, preformed polymer tape, and epoxy) (Rossatto et al., 2023). Manufacturing activities and landfill operations are two examples of the main sources of pollution that affect freshwater systems (Browne et al., 2011; Eerkes-Medrano et al., 2015). Simon-Sánchez et al. (2019), claim that rivers serve as conduits for microplastics traveling to sea and ocean regions and that the effect of tides and currents influences the accumulation of microplastics in coastal locations. Even though they are located far from coastal regions, industrial operations and urban activities on land—such as inadequate wastewater treatment systems or solid waste disposal—are the root causes of these problems. The pollutants discharged from these regions find their way into rivers, lakes, river mouths, oceans, and seas (Vaid et al., 2021). However, certain factors, such as population density and dams that produce a high amount of particles in the surrounding region (H. Zhang, 2017) may be connected with microplastic concentrations (Valine et al., 2020). Furthermore, soil can introduce microplastics into water systems. Microplastics can enter the topsoil layer and then move through leaching, agricultural practices, and bioturbation—the mixing of sedimentary material by living organisms—to the subsurface, where they may eventually find their way to groundwater or other nearby water sources (Bläsing & Amelung, 2018; Li et al., 2020).

Additionally, there is evidence that direct pollution is the main cause of microplastic accumulation in rivers, lakes, and other small water bodies. Due to dispersion throughout the river flow, the concentration of microplastics diminishes as water moves from rivers to the ocean. This suggests that these particles are being transported into offshore settings via rivers and continental water bodies (Luo et al., 2019). Water body monitoring should thus be carried out as a complicated network rather than in isolation. Furthermore, based on their hydrological uniqueness, various kinds of water bodies contain distinct kinds of microplastics with varied geometries. For instance, the flow and movement of water tend to resuspend these particles rather than allow them to settle, which is why microplastics are more frequently discovered in high-density river flows (Nizzetto et al., 2016).

According to Dris et al. (2016), there was a trace quantity of fiber-like microplastics in the air in the Paris metropolitan region. Through an iron funnel that was fastened to a glass bottle within an opaque box, they were able to gather these particles from the top of a structure. In addition to photo-oxidative degradation in the environment, wind friction and/or abrasion against other environmental particles, as well as the breakdown of clothing during drying, can all cause these tiny fibers to appear in the air and eventually break down into fine particles (Geyer et al., 2023).

3.6 Organic pollutants and micropollutants

The terms total organic carbon (TOC), dissolved organic carbon (DOC), chemical oxygen demand (COD), and biological oxygen demand (BOD) can all be used to describe organic matter in the environment. According to Dommain et al. (2011), non-anthropogenic DOC is mostly found naturally in coastal areas that are rich in organic matter, such as peatlands, which are often located in Sumatra and Kalimantan islands. Coastal waters get contaminated due to the large elevation of these levels caused by human-induced disasters. For example, in Sumatra and Kalimantan, peatland fires brought on by deforestation for oil palm plantations greatly increase fluvial DOC (Sazawa et al., 2018). The 2006 volcanic mud eruption in East Java, which resulted from the explosion of a commercial gas well, quadrupled the riverine export of TOC to the sea when compared to pre-accident values (Jennerjahn et al., 2013; Kure et al., 2014; Sidik et al., 2016).

Due to their toxicity, persistence, and ability to bioaccumulate in aquatic environments, a particular class of non-biodegradable organic molecules known as persistent organic pollutants (POPs) has drawn attention in the last 10 years. Dichlorodiphenyltrichloroethane (DDT), di-isopropylnaphthalene (DIPN), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine insecticides, and di-isopropylnaphthalene (DIPN) are some chemicals in this group that are used in industry, mining, and farming (Choi et al., 2017). The majority of these POP pesticides are already illegal; PP 22/2021 governs those that aren't. This choice establishes limits for contaminants found in water samples, such as pesticides, phenols, PCBs, PAHs, and tributyltin (TBT) (Adyasari et al., 2021). Micropollutants are chemicals that are found in very high amounts compared to studies done in other river and coastal systems in Asia, the US, and Europe. These chemicals come from specific sources and are most important in cities. These compounds include flame retardants, disinfectants, ingredients found in sunscreens and insect repellents, pain relievers, stimulants, and nicotine (Dsikowitzky et al., 2016).

In addition, chlorinated organic pollutants (COPs) are known to be prevalent, persistent, and toxic substances that are typically found in anaerobic environments. As a result, they are classified as persistent organic pollutants (POPs) (P. Gong et al., 2021; X. Gong et al., 2021; He et al., 2005; Olisah et al., 2021; Prince et al., 2020; Yuan, Li, et al., 2021; Yuan, Shentu, et al., 2021; M. Zhu, Feng, et al., 2019; M. Zhu, Zhang, et al., 2019; X. Zhu et al., 2019). Time and rigorous environmental conditions are necessary for the full degradation of the overall COP, particularly for extremely complex, structured COPs. Another great way to get rid of chlorine-containing compounds in nature is through anaerobic biodegradation (He et al., 2005; Olisah et al., 2021; Prince et al., 2020; Yuan, Li, et al., 2021; Yuan, Shentu, et al., 2021; M. Zhu, Feng, et al., 2019). However, there are a number of possible hazards since anaerobic COP dechlorination procedures are typically not fully completed (X. Gong et al., 2021).

3.7 Pesticide pollution

Because they shield crops from pests and illnesses, pesticides have become a necessary part of modern agricultural systems. However, in order to achieve the SDGs, their usage must be curtailed. But because of their widespread use, lengthy half-lives, and strong persistence in soil and aquatic ecosystems, they have harmed life sources and exceeded Earth's planetary bounds, having detrimental effects on the environment and public health (Raj et al., 2023). Over the last few decades, pesticides have eliminated illnesses in numerous parts of the world and enhanced agricultural production by reducing worms, pests, and undesirable animals (Bhardwaj & Saraf, 2014). Nevertheless, not all pesticides are good, and a large portion of them are non-retrievable, contributing to pollution and adverse health effects (Nahhal & Nahhal, 2021). One of the things contributing to the proliferation of pesticides and making their environmental impact worse is the recent change in temperature. Chiu et al. (2017) predict that future temperature rises will lead to a rise in pesticide use, worsening the ecological effects of pesticides.

Insecticides, nematicides, herbicides, rodenticides, and fungicides are just a few of the chemical substances that are widely used in global agriculture to eradicate pests that negatively impact plant health. All together, these substances are known as pesticides. Pesticides have long-term negative effects on various organism groups, including humans who depend on them, as well as livestock, insects, pollinators, soil microbes, and earthworm species (Raj et al., 2021; Raj & Kumar, 2022). Despite being helpful for farmers, pesticides can help address the growing world hunger needs of the world. Research revealed that on 64% of agricultural land globally, pesticide chemical levels were found to be higher than industry norms for "no-effect levels." With pesticide concentrations 1000 times higher than the no-effect threshold, nearly a third of agricultural land was found to have high-risk pesticide levels. After looking at more than 100 agricultural chemicals used in 168 different nations, research published in Nature Geoscience came to the conclusion that there is a "widespread risk of pesticide contamination globally." This study took into account the possibility of contaminating soil, groundwater, the atmosphere, and surface water. China makes up more than half of Asia's 1.9 million square mile pollution risk zone, which is the greatest in the world, according to the report. Scientists fear that overuse of pesticides may exacerbate the situation, upset ecosystems, and harm vital water supplies that are necessary for human and animal existence (Tang et al., 2021).

According to Liu & Lin (2005), the majority of pesticide chemicals have an impact on cholinesterase enzymes, which regulate the amount of acetylcholine required for nerve activity. Poisoning with organochlorines and organophosphates frequently results in myalgia, twitching in the muscles, convulsions, and finally death. Even at low exposure levels, these effects may manifest (Sporty et al., 2010). Some pesticides, like organophosphates and organochlorines, phosphorylate acetylcholinesterase (AChE). This starts the "aging" response, a process that breaks down cells from the inside out (Millard et al., 1999). This phosphorylation mechanism, which takes place at the hydroxyl serine group in the active site of AChE, renders acetylcholine inactive. Identifying pesticides accurately in environmental samples is essential for developing precise pesticide degradation techniques that don't compromise soil health. Over the past 50 years, many techniques have been used to find pesticide compounds. These include ion mobility spectrometry (IMS) (Diauudin et al., 2019), Fourier-transform infrared spectroscopy (FTIR) (Gäb et al., 2009; Raj & Kumar, 2022), liquid chromatography (LC) (Campanale et al., 2021), and gas chromatography (GC) (Baidoo & Teixeira Benites, 2019).

3.8 Point and nonpoint sources agricultural pollution

More than 80% of the water used globally comes from agriculture, which is also the main source of surface water and global water pollution (Akinyemi & Speranza, 2022; Tatlhego et al., 2022). Changes in rural industry, economic structures, and land usage have resulted from ongoing urbanization and the fast economic development of agriculture. Contemporary agriculture has become increasingly dependent on chemical fertilizers, insecticides, and feed due to changes in the industrial landscape, labor shortages, and rising consumer demand for food items of both high quality and quantity. Excessive nitrogen and phosphorus fertilizers are among the inputs that are frequently found in rural regions. These nutrients contaminate rural settings as non-point source pollution from agriculture by seeping into the groundwater and entering surface water through runoff (Chen et al., 2023).

Because of their dispersed origins and intricate creation methods, non-point sources from agriculture are difficult to monitor and regulate (Jin et al., 2019). Also, non-point sources are now a major source of pollutants like nitrogen and phosphorus. These pollutants cause issues like eutrophication in bodies of water, groundwater pollution, and the spread of pathogenic bacteria because rural economic development and environmental protection are not aligned (Fan et al., 2019).

3.9 River water pollution control in Indonesia

The National Water Law Number 17 of 2019 governs the management of water resources and addresses pollution control, quantity conservation, quality control, and source preservation. Environmental risks are addressed in Law No. 32/2009 concerning environmental protection and management. According to this law, any activity that could have a major impact on the environment is required to carry out an environmental risk analysis, as outlined in Government Regulation No. 5 of 2021, the most recent national regulation.

The six components of environmental protection and management include planning, usage, control, maintenance, supervision, and law enforcement, according to Law Number 32 of 2009 on Environmental Protection and Management. The purpose of this is to gather statistics and information on water resources, among other natural resources. Environmental approval; management of water and air quality; management of sea quality; control of environmental damage; management of hazardous and non-hazardous waste; guarantor data for environmental function restoration; environmental information system; coaching and supervision; and imposition of administrative sanctions are all governed by Government Regulation No. 22 of 2021 on the Implementation of Environmental Protection and Management. The purpose of oversight and enforcement of environmental law is to guarantee that the terms set forth during the planning stage of a business and/or activity are carried out as intended. Violations of the obligations in the Environmental Approval of Business Licensing or Government Approval will result in remedial action. Using the ultimum remedium concept and going through the steps of administrative sanction application, law enforcement is applied. Furthermore, the primary tool for reducing water pollution is Government Regulation No. 82 of 2001 on Air Quality Management and Air Pollution Control. Regrettably, despite the use of all these legal tools in Indonesian rivers, the Cisadane River's water quality has recently seen an increase in pollution (Rarasati & Fadhila, 2017). Despite the legal products that are already in place, the river's worsening water quality problems point to ineffective policy execution. As a result, the government must create strategies to improve current laws, such as those pertaining to water management.

3.10 Future Scope of Research

In terms of the study's future scope, there are many chances to use a variety of cutting-edge instruments and technologies to evaluate water quality indices and characteristics, giving pertinent authorities exact information they may use to make future judgments. The assessment of contaminants in relation to the uncertainty of several water quality metrics is one of the research's limitations. The selection of these contaminants was based on the anthropogenic pollutant abundance in Indonesian rivers that share comparable geographic circumstances to the Cisadane River. In developed countries, technologies like Chemically Enhanced Primary Treatment (CEPT) and Advanced Integrated Wastewater Ponds (AIWP) are helpful tools for assessing water quality and stopping the deterioration of river water quality due to pollutants from human activity (Ghimire et al., 2022). As a result, sensitivity analysis will be able to be used in the future to assess alternative technologies under various conditions, as well as parameter uncertainties and confidence intervals, in order to make better technological decisions.

Additionally, a Fuzzy Comprehensive Water Quality Index (FCWQI) model may be developed by utilizing mathematical approaches like fuzzy decision-making to estimate several water quality parameters such as DO, BOD, COD, and pH (Singh et al., 2019). Such models may be applied as decision support systems for future water quality estimation in urban rivers such as the Cisadane River. They can also be helpful for other beneficial uses, such as irrigation, regulated garbage disposal, drinking water, and more.

4. Conclusions

Surface water is particularly susceptible to pollution and contamination since it serves as the main supply of water for human use. Rapid industrialization and urbanization, poor sanitation, excessive usage, and uneven oversight make the problem worse. As a result, in recent decades, surface water quality testing, monitoring, and management have drawn a lot of scholarly interest and produced a large body of study. Therefore, this study uses a systematic literature review (SLR) technique to synthesize and assess previous research in the field.

A summary of the Cisadane River's environmental circumstances, Indonesia's overall river conditions, and the country's typical levels of pollution are given in this review. The report also outlines government initiatives to reduce river pollution by producing a number of goods that are allowed. Policymakers need to be aware of the potential costs and trade-offs involved with sacrificing the health of urban waterways in order to achieve other objectives. In order to enhance the health of rivers, policy decisions must be reevaluated. Policymakers can derive insights from this research to develop sustainable policies to stop the anthropogenic degradation of river water quality by utilizing the descriptions that have been offered.

To sum up, this review makes several significant contributions: (a) it describes the characteristics of the Cisadane River and provides an overview of all Indonesian rivers; (b) it identifies and discusses specific pollution from water quality parameters, including its physicochemical properties and effects on water sources and usage; (c) it discusses river water pollution control in Indonesia, emphasizing policies from legal products that are currently in place; and, finally, (d) it makes recommendations for future research directions.

Acknowledgement

The authors express gratitude to the IASSSF team for their support in the writing of this research.

Author Contribution

The authors made full contributions to the writing of this article.

Funding

This research did not utilize external funding.

Ethical Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Conflicts of Interest

The authors declare no conflicts of interest.

Open Access

References

Adyasari, D., Pratama, M. A., Teguh, N. A., Sabdaningsih, A., Kusumaningtyas, M. A., & Dimova, N. (2021). Anthropogenic impact on Indonesian coastal water and ecosystems: Current status and future opportunities. *Marine Pollution Bulletin*, 171, 112689. https://doi.org/https://doi.org/10.1016/j.marpolbul.2021.112689

Aisyah, S. (2014). Annual Water Quality Condition of Cisadane Downstream, West Java–Banten. *International Conference on Ecohydrology (ICE): Research Center For Limnology-Indonesian Institute Of Sciences*, 405–413.

Akinyemi, F. O., & Ifejika Speranza, C. (2022). Agricultural landscape change impact on the quality of land: An African continent-wide assessment in gained and displaced agricultural lands. *International Journal of Applied Earth Observation and Geoinformation*, 106, 102644. https://doi.org/https://doi.org/10.1016/j.jag.2021.102644

Ali, M. M., Rahman, S., Islam, M. S., Rakib, M. R. J., Hossen, S., Rahman, M. Z., Kormoker, T., Idris, A. M., & Phoungthong, K. (2022). Distribution of heavy metals in water and sediment of an urban river in a developing country: A probabilistic risk assessment. *International Journal of Sediment Research*, 37(2), 173–187. https://doi.org/https://doi.org/10.1016/j.ijsrc.2021.09.002

Amal Raj, A. R., Mylsamy, P., Sivasankar, V., Kumar, B. S., Omine, K., & Sunitha, T. G. (2023). Heavy metal pollution of river water and eco-friendly remediation using potent microalgal species. *Water Science and Engineering*. https://doi.org/https://doi.org/10.1016/j.wse.2023.04.001

Baidoo, E. E. K., & Teixeira Benites, V. (2019). *Mass Spectrometry-Based Microbial Metabolomics: Techniques, Analysis, and Applications. In E. E. K. Baidoo (Ed.), Microbial Metabolomics: Methods and Protocols* (pp. 11–69). Springer New York. https://doi.org/10.1007/978-1-4939-8757-3_2

Bhagat, J., Nishimura, N., & Shimada, Y. (2021). Toxicological interactions of microplastics/nanoplastics and environmental contaminants: Current knowledge and future perspectives. *Journal of Hazardous Materials*, 405, 123913. https://doi.org/https://doi.org/10.1016/j.jhazmat.2020.123913

Bhardwaj, J. K., & Saraf, P. (2014). Malathion-induced granulosa cell apoptosis in caprine antral follicles: An ultrastructural and flow cytometric analysis. *Microscopy and Microanalysis*, 20(6), 1861–1868. https://doi.org/10.1017/S1431927614013452

Bläsing, M., & Amelung, W. (2018). *Plastics in soil: Analytical methods and possible sources. Science of The Total Environment*, 612, 422–435. https://doi.org/https://doi.org/10.1016/j.scitotenv.2017.08.086

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T., & Thompson, R. (2011). Accumulation of Microplastic on Shorelines Woldwide: Sources and Sinks. *Environmental Science & Technology*, 45(21), 9175–9179. https://doi.org/10.1021/es201811s

Campanale, C., Massarelli, C., Losacco, D., Bisaccia, D., Triozzi, M., & Uricchio, V. F. (2021). The monitoring of pesticides in water matrices and the analytical criticalities: A review. *TrAC Trends in Analytical Chemistry*, 144, 116423. https://doi.org/https://doi.org/10.1016/j.trac.2021.116423

Chen, T., Lu, J., Lu, T., Yang, X., Zhong, Z., Feng, H., Wang, M., & Yin, J. (2023). Agricultural non-point source pollution and rural transformation in a plain river network: Insights from Jiaxing city, China. *Environmental Pollution*, 333, 121953.

https://doi.org/https://doi.org/10.1016/j.envpol.2023.121953

Chen, Y., Zhang, Z., Qian, X., Li, J., Ji, Z., & Wu, T. (2020). *Early to mid-Paleozoic magmatic and sedimentary records in the Bainaimiao Arc: An advancing subduction-induced terrane accretion along the northern margin of the North China Craton*. Gondwana Research, 79, 263–282. https://doi.org/https://doi.org/10.1016/j.gr.2019.08.012

Chiu, M.-C., Hunt, L., & Resh, V. H. (2017). Climate-change influences on the response of macroinvertebrate communities to pesticide contamination in the Sacramento River, California watershed. *Science of The Total Environment*, 581–582, 741–749. https://doi.org/https://doi.org/10.1016/j.scitotenv.2017.01.002

Choi, Y.-Y., Baek, S.-R., Kim, J.-I., Choi, J.-W., Hur, J., Lee, T.-U., Park, C.-J., & Lee, B. J. (2017). Characteristics and Biodegradability of Wastewater Organic Matter in Municipal Wastewater Treatment Plants Collecting Domestic Wastewater and Industrial Discharge. *Water*, 9(6). https://doi.org/10.3390/w9060409

Deshmukh, S., Bala, K., & Kumar, R. (2019). Selection of microalgae species based on their lipid content, fatty acid profile and apparent fuel properties for biodiesel production. *Environmental Science and Pollution Research*, 26(24), 24462–24473. https://doi.org/10.1007/s11356-019-05692-z

Diauudin, F. N., Rashid, J. I. A., Knight, V. F., Wan Yunus, W. M. Z., Ong, K. K., Kasim, N. A. M., Abdul Halim, N., & Noor, S. A. M. (2019). A review of current advances in the detection of organophosphorus chemical warfare agents based biosensor approaches. *Sensing and Bio-Sensing Research*, 26, 100305. https://doi.org/https://doi.org/10.1016/j.sbsr.2019.100305

Ding, L., Guo, X., Du, S., Cui, F., Zhang, Y., Liu, P., Ouyang, Z., Jia, H., & Zhu, L. (2022). Insight into the Photodegradation of Microplastics Boosted by Iron (Hydr)oxides. *Environmental Science & Technology*, 56(24), 17785–17794. https://doi.org/10.1021/acs.est.2c07824

Dommain, R., Couwenberg, J., & Joosten, H. (2011). Development and carbon sequestration of tropical peat domes in south-east Asia: links to post-glacial sea-level changes and Holocene climate variability. *Quaternary Science Reviews*, 30(7), 999–1010. https://doi.org/https://doi.org/10.1016/j.quascirev.2011.01.018

Dris, R., Gasperi, J., Saad, M., Mirande, C., & Tassin, B. (2016). Synthetic fibers in atmospheric fallout: A source of microplastics in the environment?, *Marine Pollution Bulletin*, 104(1), 290–293. https://doi.org/10.1016/j.marpolbul.2016.01.006

Dsikowitzky, L., Sträter, M., Dwiyitno, Ariyani, F., Irianto, H. E., & Schwarzbauer, J. (2016). First comprehensive screening of lipophilic organic contaminants in surface waters of the megacity Jakarta, Indonesia. *Marine Pollution Bulletin*, 110(2), 654–664. https://doi.org/https://doi.org/10.1016/j.marpolbul.2016.02.019

Duan, L., Qin, Y., Meng, X., Liu, Y., Zhang, T., & Chen, W. (2023). Sulfide- and UV-induced aging differentially affect contaminant-binding properties of microplastics derived from commercial plastic products. *Science of The Total Environment*, 869, 161800. https://doi.org/https://doi.org/10.1016/j.scitotenv.2023.161800

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z.-I., Knowler, D. J., Lévêque, C., Naiman, R. J., Prieur-Richard, A.-H., Soto, D., Stiassny, M. L. J., & Sullivan, C. A. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews*, 81(2), 163–182. https://doi.org/https://doi.org/10.1017/S1464793105006950

Eerkes-Medrano, D., Thompson, R. C., & Aldridge, D. C. (2015). Microplastics in freshwater systems: A review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. *Water Research*, 75, 63–82. https://doi.org/https://doi.org/10.1016/j.watres.2015.02.012

El-Nahhal, Y., & El-Nahhal, I. (2021). Cardiotoxicity of some pesticides and their amelioration. *Environmental Science and Pollution Research*, 28(33), 44726–44754. https://doi.org/10.1007/s11356-021-14999-9

Engloner, A. I., Németh, K., Dobosy, P., & Óvári, M. (2023). Exploring the trend effects of diffuse anthropogenic pollution in a large river passing through a densely populated area. *Heliyon*, 9(9), e20120. https://doi.org/https://doi.org/10.1016/j.heliyon.2023.e20120

Fadlillah, L. N., Utami, S., Rachmawati, A. A., Jayanto, G. D., & Widyastuti, M. (2023). Ecological risk and source identifications of heavy metals contamination in the water and surface sediments from anthropogenic impacts of urban river, Indonesia. *Heliyon*, 9(4), e15485. https://doi.org/https://doi.org/10.1016/j.heliyon.2023.e15485

Fan, L., Yuan, Y., Ying, Z., Lam, S. K., Liu, L., Zhang, X., Liu, H., & Gu, B. (2019). Decreasing farm number benefits the mitigation of agricultural non-point source pollution in China. *Environmental Science and Pollution Research*, 26(1), 464–472. https://doi.org/10.1007/s11356-018-3622-6

Fan, Q., He, J., Xue, H., Lü, C., Sun, Y., Shen, L., Liang, Y., & Bai, S. (2008). Heavy metal pollution in the Baotou section of the Yellow River, China. *Chemical Speciation and Bioavailability*, 20(2), 65–76. https://doi.org/10.3184/095422908X322824

Firmansyah, Y. W., Widiyantoro, W., Fuadi, M. F., Afrina, Y., & Hardiyanto, A. (2021). Dampak pencemaran sungai di Indonesia terhadap gangguan kesehatan: Literature Review. *Jurnal Riset Kesehatan Poltekkes Depkes Bandung*, 13(1), 120–133.

Gäb, J., Melzer, M., Kehe, K., Richardt, A., & Blum, M.-M. (2009). Quantification of hydrolysis of toxic organophosphates and organophosphonates by diisopropyl fluorophosphatase from Loligo vulgaris by in situ Fourier transform infrared spectroscopy. *Analytical Biochemistry*, 385(2), 187–193. https://doi.org/https://doi.org/10.1016/j.ab.2008.11.012

Geyer, R., Jambeck, J. R., & Law, K. L. (2023). Production, use, and fate of all plastics ever made. *Science Advances*, 3(7), e1700782. https://doi.org/10.1126/sciadv.1700782

Ghimire, S., Pokhrel, N., Pant, S., Gyawali, T., Koirala, A., Mainali, B., Angove, M. J., & Paudel, S. R. (2022). Assessment of technologies for water quality control of the Bagmati River in Kathmandu valley, Nepal. *Groundwater for Sustainable Development*, 18, 100770. https://doi.org/https://doi.org/10.1016/j.gsd.2022.100770

Gong, P., Xu, H., Wang, C., Chen, Y., Guo, L., & Wang, X. (2021). Persistent organic pollutant cycling in forests. *Nature Reviews Earth & Environment*, 2(3), 182–197. https://doi.org/10.1038/s43017-020-00137-5

Gong, X., Ding, Q., Jin, M., Zhao, Z., Zhang, L., Yao, S., & Xue, B. (2021). Recording and response of persistent toxic substances (PTSs) in urban lake sediments to anthropogenic activities. *Science of The Total Environment*, 777, 145977. https://doi.org/https://doi.org/10.1016/j.scitotenv.2021.145977

Häder, D.-P., Banaszak, A. T., Villafañe, V. E., Narvarte, M. A., González, R. A., & Helbling, E. W. (2020). Anthropogenic pollution of aquatic ecosystems: Emerging problems with global implications. *Science of The Total Environment*, 713, 136586. https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.136586

He, Y., Xu, J., Tang, C., & Wu, Y. (2005). Facilitation of pentachlorophenol degradation in the rhizosphere of ryegrass (Lolium perenne L.). *Soil Biology and Biochemistry*, 37(11), 2017–2024. https://doi.org/https://doi.org/10.1016/j.soilbio.2005.03.002

Hoang, H.-G., Chiang, C.-F., Lin, C., Wu, C.-Y., Lee, C.-W., Cheruiyot, N. K., Tran, H.-T., & Bui, X.-T. (2021). Human health risk simulation and assessment of heavy metal contamination in a river affected by industrial activities. *Environmental Pollution*, 285, 117414. https://doi.org/https://doi.org/10.1016/j.envpol.2021.117414

Hoang, H.-G., Lin, C., Chiang, C.-F., Bui, X.-T., Lukkhasorn, W., Bui, T.-P.-T., Tran, H.-T., Vo, T.-D.-H., Le, V.-G., & Nghiem, L. D. (2021). The Individual and Synergistic Indexes for Assessments of Heavy Metal Contamination in Global Rivers and Risk: a Review. *Current Pollution Reports*, 7(3), 247–262. https://doi.org/10.1007/s40726-021-00196-2

Hoang, H.-G., Lin, C., Tran, H.-T., Chiang, C.-F., Bui, X.-T., Cheruiyot, N. K., Shern, C.-C., & Lee, C.-W. (2020). Heavy metal contamination trends in surface water and sediments of a river in a highly-industrialized region. *Environmental Technology & Innovation*, 20, 101043. https://doi.org/https://doi.org/10.1016/j.eti.2020.101043

Jennerjahn, T. C., Jänen, I., Propp, C., Adi, S., & Nugroho, S. P. (2013). Environmental impact of mud volcano inputs on the anthropogenically altered Porong River and Madura Strait coastal waters, Java, Indonesia. *Estuarine, Coastal and Shelf Science*, 130, 152–160. https://doi.org/https://doi.org/10.1016/j.ecss.2013.04.007

Jenner, L. C., Rotchell, J. M., Bennett, R. T., Cowen, M., Tentzeris, V., & Sadofsky, L. R. (2022). Detection of microplastics in human lung tissue using μFTIR spectroscopy. *Science of The Total Environment*, 831, 154907. https://doi.org/https://doi.org/10.1016/j.scitotenv.2022.154907

Jiménez-López, A. M., & Hincapié-Llanos, G. A. (2022). Identification of factors affecting the reduction of VOC emissions in the paint industry: Systematic literature review - SLR. *Progress in Organic Coatings*, 170, 106945. https://doi.org/https://doi.org/10.1016/j.porgcoat.2022.106945

Jin, G., Li, Z., Deng, X., Yang, J., Chen, D., & Li, W. (2019). An analysis of spatiotemporal patterns in Chinese agricultural productivity between 2004 and 2014. *Ecological Indicators*, 105, 591–600. https://doi.org/https://doi.org/10.1016/j.ecolind.2018.05.073

Kim, J.-H., Yu, Y.-B., & Choi, J.-H. (2021). Toxic effects on bioaccumulation, hematological parameters, oxidative stress, immune responses and neurotoxicity in fish exposed to microplastics: A review. *Journal of Hazardous Materials*, 413, 125423. https://doi.org/https://doi.org/10.1016/j.jhazmat.2021.125423

Kure, S., Winarta, B., Takeda, Y., Udo, K., Umeda, M., Mano, A., & Tanaka, H. (2014). Effects of mud flows from the LUSI mud volcano on the Porong River estuary, Indonesia. *Journal of Coastal Research*, 70(sp1), 568–573. https://doi.org/10.2112/SI70-096.1

Li, C., Busquets, R., & Campos, L. C. (2020). Assessment of microplastics in freshwater systems: A review. *Science of The Total Environment*, 707, 135578. https://doi.org/https://doi.org/10.1016/j.scitotenv.2019.135578

Lin, Y., Wu, M., Fang, F., Wu, J., & Ma, K. (2021). Characteristics and influencing factors of heavy metal pollution in surface dust from driving schools of Wuhu, China. *Atmospheric Pollution Research*, 12(2), 305–315. https://doi.org/https://doi.org/10.1016/j.apr.2020.11.012

Li, S.-L., Zhang, H., Yi, Y., Zhang, Y., Qi, Y., Mostofa, K. M. G., Guo, L., He, D., Fu, P., & Liu, C.-Q. (2023). Potential impacts of climate and anthropogenic-induced changes on DOM dynamics among the major Chinese rivers. *Geography and Sustainability*, 4(4), 329–339. https://doi.org/https://doi.org/10.1016/j.geosus.2023.07.003

Liu, G., & Lin, Y. (2005). Electrochemical Sensor for Organophosphate Pesticides and Nerve Agents Using Zirconia Nanoparticles as Selective Sorbents. *Analytical Chemistry*, 77(18), 5894–5901. https://doi.org/10.1021/ac050791t

Liu, J.-J., & Liu, Y. (2013). Study on heavy metals and ecological risk assessment from Gansu, Ningxia and Inner Mongolia sections of the Yellow River, China. *Guang Pu Xue Yu Guang Pu Fen Xi/Spectroscopy and Spectral Analysis,* 33(12), 3249–3254. https://doi.org/10.3964/j.issn.1000-0593(2013)12-3249-06

Liu, J., & Zheng, G. (2020). Emission of volatile organic compounds from a small-scale municipal solid waste transfer station: Ozone-formation potential and health risk assessment. *Waste Management*, 106, 193–202. https://doi.org/https://doi.org/10.1016/j.wasman.2020.03.031

Li, X., Wu, P., Delang, C. O., He, Q., & Zhang, F. (2021). Spatial-temporal variation, ecological risk, and source identification of nutrients and heavy metals in sediments in the peri-urban riverine system. *Environmental Science and Pollution Research*, 28(45), 64739–64756. https://doi.org/10.1007/s11356-021-15601-y

Li, Z., Chao, M., He, X., Lan, X., Tian, C., Feng, C., & Shen, Z. (2022). Microplastic bioaccumulation in estuary-caught fishery resource. *Environmental Pollution*, 306, 119392. https://doi.org/https://doi.org/10.1016/j.envpol.2022.119392

Long, X., Liu, F., Zhou, X., Pi, J., Yin, W., Li, F., Huang, S., & Ma, F. (2021). Estimation of spatial distribution and health risk by arsenic and heavy metals in shallow groundwater around Dongting Lake plain using GIS mapping. *Chemosphere*, 269, 128698. https://doi.org/https://doi.org/10.1016/j.chemosphere.2020.128698

Looi, L. J., Aris, A. Z., Yusoff, F. M., Isa, N. M., & Haris, H. (2019). Application of enrichment factor, geoaccumulation index, and ecological risk index in assessing the elemental pollution status of surface sediments. *Environmental Geochemistry and Health*, 41(1), 27–42. https://doi.org/10.1007/s10653-018-0149-1

Luo, W., Su, L., Craig, N. J., Du, F., Wu, C., & Shi, H. (2019). Comparison of microplastic pollution in different water bodies from urban creeks to coastal waters. *Environmental Pollution*, 246, 174–182. https://doi.org/https://doi.org/10.1016/j.envpol.2018.11.081

Mahabeer, P., & Tekere, M. (2021). Anthropogenic pollution influences on the physical and chemical quality of water and sediments of the umdloti river system, Kwazulu-Natal. *Physics and Chemistry of the Earth*, Parts A/B/C, 123, 103030. https://doi.org/https://doi.org/10.1016/j.pce.2021.103030

Mak, C. W., Ching-Fong Yeung, K., & Chan, K. M. (2019). Acute toxic effects of polyethylene microplastic on adult zebrafish. *Ecotoxicology and Environmental Safety*, 182, 109442. https://doi.org/https://doi.org/10.1016/j.ecoenv.2019.109442

Miao, C., Ni, J., & Borthwick, A. G. L. (2010). Recent changes of water discharge and sediment load in the Yellow River basin, China. *Progress in Physical Geography*, 34(4), 541–561. https://doi.org/10.1177/0309133310369434

Millard, C. B., Kryger, G., Ordentlich, A., Greenblatt, H. M., Harel, M., Raves, M. L., Segall, Y., Barak, D., Shafferman, A., Silman, I., & Sussman, J. L. (1999). Crystal Structures of Aged Phosphonylated Acetylcholinesterase: Nerve Agent Reaction Products at the Atomic Level,. *Biochemistry*, 38(22), 7032–7039. https://doi.org/10.1021/bi982678l

Namara, I., Hartono, D. M., Latief, Y., & Moersidik, S. S. (2020). The Effect of Land Use Change on the Water Quality of Cisadane River Of the Tangerang City. *Journal of Engineering and Applied Sciences*, 15(9), 2128–2134. https://www.researchgate.net/publication/341286414_The_Effect_of_Land_Use_Change_on_the_Water_Quality_of_Cisadane_River_Of_the_Tangerang_City

Nizzetto, L., Bussi, G., Futter, M. N., Butterfield, D., & Whitehead, P. G. (2016). A theoretical assessment of microplastic transport in river catchments and their retention by soils and river sediments. *Environmental Science: Processes & Impacts*, 18(8), 1050–1059. https://doi.org/10.1039/C6EM00206D

Olisah, C., Adams, J. B., & Rubidge, G. (2021). The state of persistent organic pollutants in South African estuaries: A review of environmental exposure and sources. *Ecotoxicology and Environmental Safety*, 219, 112316. https://doi.org/https://doi.org/10.1016/j.ecoenv.2021.112316

Prince, K. D., Taylor, S. D., & Angelini, C. (2020). A Global, Cross-System Meta-Analysis of Polychlorinated Biphenyl Biomagnification. *Environmental Science and Technology*, 54(18), 10989–11001. https://doi.org/10.1021/acs.est.9b07693

Purwati, S. U., Lestari, N. S., & Nasution, E. L. (2019). Water quality assessment of Cisadane River using pollution indicator parameters. *IOP Conference Series: Earth and Environmental Science*, 407(1), 012009. https://doi.org/10.1088/1755-1315/407/1/012009

Rachmawati, I. P., Riani, E., & Riadi, A. (2020). Status mutu air dan beban pencemaran Sungai Krukut, DKI Jakarta. *Journal of Natural Resources and Environmental Management*, 10(2), 220–233. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwiUqdPFteOEAxUIfGwGHdQIAxIQFnoECA0QAQ&url=https%3A%2F%2Fjournal.ipb.ac.id%2Findex.php%2Fjpsl%2Farticle%2Fdownload%2F14617%2F20079&usg=AOvVaw2eIWStIkgv_Vhsuh4ZoIdr&opi=89978449

Raj, A., Dubey, A., Malla, M. A., & Kumar, A. (2023). Pesticide pestilence: Global scenario and recent advances in detection and degradation methods. *Journal of Environmental Management*, 338, 117680. https://doi.org/https://doi.org/10.1016/j.jenvman.2023.117680

Raj, A., & Kumar, A. (2022). Recent advances in assessment methods and mechanism of microbe-mediated chlorpyrifos remediation. *Environmental Research*, 214, 114011.

https://doi.org/https://doi.org/10.1016/j.envres.2022.114011

Raj, A., Kumar, A., & Dames, J. F. (2021). Tapping the Role of Microbial Biosurfactants in Pesticide Remediation: An Eco-Friendly Approach for Environmental Sustainability. *Frontiers in Microbiology*, 12. https://www.frontiersin.org/articles/10.3389/fmicb.2021.791723

Rarasati, A. D., & Fadhila Muhammad, L. T. (2017). Risk analyze: Management water quality cisadane river by project approach. *MALAYSIAN JOURNAL OF INDUSTRIAL TECHNOLOGY* (MJIT). https://www.researchgate.net/publication/322386392_RISK_ANALYZE_MANAGEMENT_WATER_QUALITY_CISADANE_RIVER_BY_PROJECT_APPROACH

Rossatto, A., Arlindo, M. Z. F., de Morais, M. S., de Souza, T. D., & Ogrodowski, C. S. (2023). Microplastics in aquatic systems: A review of occurrence, monitoring and potential environmental risks. *Environmental Advances*, 13, 100396. https://doi.org/https://doi.org/10.1016/j.envadv.2023.100396

Sazawa, K., Wakimoto, T., Fukushima, M., Yustiawati, Y., Syawal, M. S., Hata, N., Taguchi, S., Tanaka, S., Tanaka, D., & Kuramitz, H. (2018). Impact of Peat Fire on the Soil and Export of Dissolved Organic Carbon in Tropical Peat Soil, Central Kalimantan, Indonesia. *ACS Earth and Space Chemistry*, 2(7), 692–701. https://doi.org/10.1021/acsearthspacechem.8b00018

Shafiei, M., Rahmani, M., Gharari, S., Davary, K., Abolhassani, L., Teimouri, M. S., & Gharesifard, M. (2022). Sustainability assessment of water management at river basin level: Concept, methodology and application. *Journal of Environmental Management*, 316, 115201. https://doi.org/https://doi.org/10.1016/j.jenvman.2022.115201

Shi, X., Chen, Z., Wei, W., Chen, J., & Ni, B.-J. (2023). Toxicity of micro/nanoplastics in the environment: Roles of plastisphere and eco-corona. *Soil & Environmental Health*, 1(1), 100002. https://doi.org/https://doi.org/10.1016/j.seh.2023.100002

Sidik, F., Neil, D., & Lovelock, C. E. (2016). Effect of high sedimentation rates on surface sediment dynamics and mangrove growth in the Porong River, Indonesia. *Marine Pollution Bulletin*, 107(1), 355–363. https://doi.org/https://doi.org/10.1016/j.marpolbul.2016.02.048

Simon-Sánchez, L., Grelaud, M., Garcia-Orellana, J., & Ziveri, P. (2019). River Deltas as hotspots of microplastic accumulation: The case study of the Ebro River (NW Mediterranean). *Science of The Total Environment*, 687, 1186–1196. https://doi.org/https://doi.org/10.1016/j.scitotenv.2019.06.168

Singh, A. P., Dhadse, K., & Ahalawat, J. (2019). Managing water quality of a river using an integrated geographically weighted regression technique with fuzzy decision-making model. *Environmental Monitoring and Assessment*, 191(6), 378. https://doi.org/10.1007/s10661-019-7487-z

Singh, K. P., Malik, A., & Sinha, S. (2005). Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques—a case study. *Analytica Chimica Acta*, 538(1), 355–374. https://doi.org/https://doi.org/10.1016/j.aca.2005.02.006

Slama, H. B., Chenari Bouket, A., Pourhassan, Z., Alenezi, F. N., Silini, A., Cherif-Silini, H., Oszako, T., Luptakova, L., Golińska, P., & Belbahri, L. (2021). Diversity of Synthetic Dyes from Textile Industries, Discharge Impacts and Treatment Methods. *In Applied Sciences*, 11(14). https://doi.org/10.3390/app11146255

Sonthiphand, P., Termsaithong, T., Mhuantong, W., Van Muoi, L., & Chotpantarat, S. (2023). Structure of the river sediment microbiomes impacted by anthropogenic land uses, environmental and spatial variations. *Estuarine, Coastal and Shelf Science*, 287, 108348. https://doi.org/https://doi.org/10.1016/j.ecss.2023.108348

Sporty, J. L. S., Lemire, S. W., Jakubowski, E. M., Renner, J. A., Evans, R. A., Williams, R. F., Schmidt, J. G., Schans, M. J. van der, Noort, D., & Johnson, R. C. (2010). Immunomagnetic Separation and Quantification of Butyrylcholinesterase Nerve Agent Adducts in Human Serum. *Analytical Chemistry*, 82(15), 6593–6600. https://doi.org/10.1021/ac101024z

Stapleton, M. J., Ansari, A. J., & Hai, F. I. (2023). Antibiotic sorption onto microplastics in water: A critical review of the factors, mechanisms and implications. *Water Research*, 233, 119790. https://doi.org/https://doi.org/10.1016/j.watres.2023.119790

Tang, F. H. M., Lenzen, M., McBratney, A., & Maggi, F. (2021). Risk of pesticide pollution at the global scale. *Nature Geoscience*, 14(4), 206–210. https://doi.org/10.1038/s41561-021-00712-5

Tatlhego, M., Chiarelli, D. D., Rulli, M. C., & D'Odorico, P. (2022). The value generated by irrigation in the command areas of new agricultural dams in Africa. *Agricultural Water Management*, 264, 107517. https://doi.org/https://doi.org/10.1016/j.agwat.2022.107517

Vaid, M., Sarma, K., & Gupta, A. (2021). Microplastic pollution in aquatic environments with special emphasis on riverine systems: Current understanding and way forward. *Journal of Environmental Management*, 293, 112860. https://doi.org/https://doi.org/10.1016/j.jenvman.2021.112860

Valine, A. E., Peterson, A. E., Horn, D. A., Scully-Engelmeyer, K. M., & Granek, E. F. (2020). Microplastic Prevalence in 4 Oregon Rivers Along a Rural to Urban Gradient Applying a Cost-Effective Validation Technique. *Environmental Toxicology and Chemistry*, 39(8), 1590–1598. https://doi.org/https://doi.org/10.1002/etc.4755

Varol, M. (2020). Environmental, ecological and health risks of trace metals in sediments of a large reservoir on the Euphrates River (Turkey). *Environmental Research*, 187, 109664. https://doi.org/https://doi.org/10.1016/j.envres.2020.109664

Wang, L., Bank, M. S., Rinklebe, J., & Hou, D. (2023). Plastic–Rock Complexes as Hotspots for Microplastic Generation. *Environmental Science & Technology*, 57(17), 7009–7017. https://doi.org/10.1021/acs.est.3c00662

Williams, J. A., & Antoine, J. (2020). Evaluation of the elemental pollution status of Jamaican surface sediments using enrichment factor, geoaccumulation index, ecological risk and potential ecological risk index. *Marine Pollution Bulletin*, 157, 111288. https://doi.org/https://doi.org/10.1016/j.marpolbul.2020.111288

Xiao, H., Shahab, A., Xi, B., Chang, Q., You, S., Li, J., Sun, X., Huang, H., & Li, X. (2021). Heavy metal pollution, ecological risk, spatial distribution, and source identification in sediments of the Lijiang River, China. *Environmental Pollution*, 269, 116189. https://doi.org/https://doi.org/10.1016/j.envpol.2020.116189

Xie, F., Yu, M., Yuan, Q., Meng, Y., Qie, Y., Shang, Z., Luan, F., & Zhang, D. (2022). Spatial distribution, pollution assessment, and source identification of heavy metals in the Yellow River. *Journal of Hazardous Materials*, 436, 129309. https://doi.org/https://doi.org/10.1016/j.jhazmat.2022.129309

Xu, B., Liu, F., Brookes, P. C., & Xu, J. (2018). The sorption kinetics and isotherms of sulfamethoxazole with polyethylene microplastics. *Marine Pollution Bulletin*, 131, 191–196. https://doi.org/https://doi.org/10.1016/j.marpolbul.2018.04.027

Xu, P., Peng, G., Su, L., Gao, Y., Gao, L., & Li, D. (2018). Microplastic risk assessment in surface waters: A case study in the Changjiang Estuary, China. *Marine Pollution Bulletin*, 133, 647–654. https://doi.org/https://doi.org/10.1016/j.marpolbul.2018.06.020

Yang, H. J., Jeong, H. J., Bong, K. M., Jin, D. R., Kang, T.-W., Ryu, H.-S., Han, J. H., Yang, W. J., Jung, H., Hwang, S. H., & Na, E. H. (2020). Organic matter and heavy metal in river sediments of southwestern coastal Korea: Spatial distributions, pollution, and ecological risk assessment. *Marine Pollution Bulletin*, 159, 111466. https://doi.org/https://doi.org/10.1016/j.marpolbul.2020.111466

Yuan, J., Li, S., Cheng, J., Guo, C., Shen, C., He, J., Yang, Y., Hu, P., Xu, J., & He, Y. (2021). Potential Role of Methanogens in Microbial Reductive Dechlorination of Organic Chlorinated Pollutants In Situ. *Environmental Science & Technology*, 55(9), 5917–5928. https://doi.org/10.1021/acs.est.0c08631

Yuan, J., Shentu, J., Feng, J., Lu, Z., Xu, J., & He, Y. (2021). Methane-associated micro-ecological processes crucially improve the self-purification of lindane-polluted paddy soil. *Journal of Hazardous Materials*, 407, 124839.

https://doi.org/https://doi.org/10.1016/j.jhazmat.2020.124839

Zanotti, C., Rotiroti, M., Caschetto, M., Redaelli, A., Bozza, S., Biasibetti, M., Mostarda, L., Fumagalli, L., & Bonomi, T. (2022). A cost-effective method for assessing groundwater well vulnerability to anthropogenic and natural pollution in the framework of water safety plans. *Journal of Hydrology*, 613, 128473. https://doi.org/https://doi.org/10.1016/j.jhydrol.2022.128473

Zhang, H. (2017). Transport of microplastics in coastal seas. *Estuarine, Coastal and Shelf Science*, 199, 74–86. https://doi.org/https://doi.org/10.1016/j.ecss.2017.09.032

Zhang, M., Wang, X., Liu, C., Lu, J., Qin, Y., Mo, Y., Xiao, P., & Liu, Y. (2020). Identification of the heavy metal pollution sources in the rhizosphere soil of farmland irrigated by the Yellow River using PMF analysis combined with multiple analysis methods—using Zhongwei city, Ningxia, as an example. *Environmental Science and Pollution* Research, 27(14), 16203–16214. https://doi.org/10.1007/s11356-020-07986-z

Zhang, Y., Zhang, X., Bi, Z., Yu, Y., Shi, P., Ren, L., & Shan, Z. (2020). The impact of land use changes and erosion process on heavy metal distribution in the hilly area of the Loess Plateau, China. *Science of The Total Environment*, 718, 137305. https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.137305

Zhao, J., Wu, E., Zhang, B., Bai, X., Lei, P., Qiao, X., Li, Y.-F., Li, B., Wu, G., & Gao, Y. (2021). Pollution characteristics and ecological risks associated with heavy metals in the Fuyang river system in North China. *Environmental Pollution*, 281, 116994. https://doi.org/https://doi.org/10.1016/j.envpol.2021.116994

Zhu, M., Feng, X., Qiu, G., Feng, J., Zhang, L., Brookes, P. C., Xu, J., & He, Y. (2019). Synchronous response in methanogenesis and anaerobic degradation of pentachlorophenol in flooded soil. *Journal of Hazardous Materials*, 374, 258–266. https://doi.org/https://doi.org/10.1016/j.jhazmat.2019.04.040

Zhu, M., Zhang, L., Franks, A. E., Feng, X., Brookes, P. C., Xu, J., & He, Y. (2019). Improved synergistic dechlorination of PCP in flooded soil microcosms with supplementary electron donors, as revealed by strengthened connections of functional microbial interactome. *Soil Biology and Biochemistry*, 136, 107515. https://doi.org/https://doi.org/10.1016/j.soilbio.2019.06.011

Zhu, X., Dsikowitzky, L., Kucher, S., Ricking, M., & Schwarzbauer, J. (2019). Formation and Fate of Point-Source Nonextractable DDT-Related Compounds on Their Environmental Aquatic-Terrestrial Pathway. *Environmental Science & Technology*, 53(3), 1305–1314. https://doi.org/10.1021/acs.est.8b06018

Biography of Author(s)

MUHAMMAD NABIL MAKARIM, School of Environmental Science, University of Indonesia.

- Email: muhammad.nabil28@ui.ac.id ORCID: -
- Web of Science ResearcherID: -
- Scopus Author ID: -
- Homepage: -