

A Desktop Study on the Interrelationship Between Rainwater and River Water Quality: An Overview of Environmental Impacts and Monitoring Approaches

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Abstract. This desktop study explores the connection between rainwater and river water quality, focusing on how precipitation patterns influence the chemical and physical characteristics of river systems. Rainwater is a critical factor in replenishing river flows, but it also serves as a vehicle for pollutants, especially in urban and industrial areas. This study reviews existing literature and reports on the composition of rainwater, its role in riverine pollution, and the environmental consequences of acid rain, runoff, and atmospheric deposition. The study also examines methods of monitoring water quality, emphasizing pH, turbidity, conductivity, and the presence of contaminants such as heavy metals and nutrients. Furthermore, the research highlights the importance of integrated water resource management and the development of sensors for real-time monitoring. By synthesizing available data, this overview underscores the need for proactive measures to protect water quality amidst changing climatic conditions and increasing anthropogenic pressures.

1. Introduction

Water is a blessing from God to the human, animal and plants. Water is important to the ecosystem and sustainable environment. According to Zuraini Awang (2019) [1], the demand of water increasing from 1980 to 2000 from 8.9 billion m³ to 15.5 billion m³. Rivers, is the main sources of freshwater and river highly influence by the various factors such as rainwater which most significantly to the river quality, pollution and grading. All rivers originate from a source and run downhill and combination of tiny stream and culminating in the sea or ocean [2]. Figure 1 illustrates the conventional schematic of water resources flowing from the highlands to the ocean. The river receives rainwater as a natural source; however, contaminants may be present due to atmospheric deposition and surface discharge. Malaysia experiences over 3,000mm of annual precipitation, yielding over 900 billion cubic meters of water resources each year. Surface water sources, constitute over 97% of our raw water supply for agricultural, household, and industrial applications. Understanding the interrelationship between rainwater and river water quality is essential for sustainable water management, rainwater could increase the level of pollution and change the scenario of main source of water supply in Malaysia. This paper provides an overview of the dynamics between rainwater and river water quality, reviewing available literature and synthesizing data from previous studies.

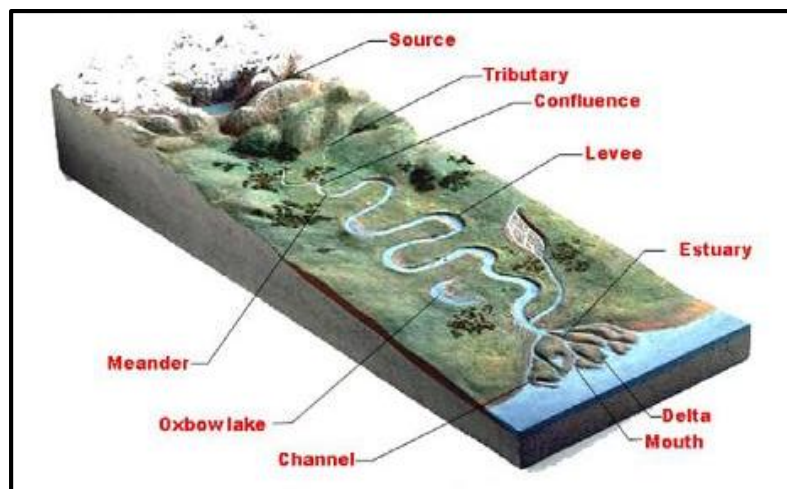


Figure 1. The typical diagram of water resources from the downhill to the sea [2]

2. Rainwater Characteristics and Sources of Contamination

Rainwater is characterised as precipitation collected from the sky to the catchment. Rainwater typically has minimal dissolved particles but includes dissolved gases (carbon, nitrogen, and sulphur oxides), leading to pH values around 5.5 or lower. In coastal areas, rainwater may contain up to 15 mg/l of chloride salt as a result of sea spray. Rainwater is deficient in alkalinity; it is acidic (low pH), low in mineral content, and corrosive to calcium-containing materials such as concrete and some metals frequently employed in domestic plumbing. The existence of chlorides exacerbates corrosivity [3].

Acid rain is a primary contributor to the degradation of water bodies, including rivers, as it alters the pH balance and can lead to the mobilization of heavy metals from soil into water sources. Rainwater collected in urban area could contain of contaminants from the road and vehicle debris and movement (rubber friction mark from vehicle tyre) which impact the quality of water. At the agriculture area the pollution could happen by using the fertiliser, same goes to industrial area which have effluent from the factory that dissolve or evaporated to the sky. All this kind of activity could be the main factor the influence the quality of rainwater which also reduce the quality of the river [4].

3. River Water Quality Parameters and Their Link to Rainwater

Water quality is important in understanding the aquatic ecosystem health level and also river condition. A lot of parameters need to take for evaluate the level of river quality for the use cluster such as drinking, agriculture, industrial and biodiversity. Rainwater actually has a significant to justify the parameter of the river usually can be polluted and also neutralised the river. Several parameters have been identifying for river quality checking: -

1) pH

pH value representing the acidic level and alkaline level of the water. Balance pH value usually between 6.5 and 8.5 for river. According to Annex by DOE, the level of acceptance for river to human, aquatic, and recreation are 6.5 to 8.5 of the pH value reading [5]. Rainwater in the area with air pollution, can be acidic due to attend of the dissolve gases such as carbon dioxide or sulphur dioxide. Due to this matter, the acid rain will produce and could level down the pH value of the river and harmful to certain aquatic species.

2) Dissolve oxygen (DO)

Dissolve oxygen important for fish and others aquatic organism. The high level of oxygen could produce the good ecosystem of the river and healthy river, but if the level is low, will cause of pollution and imbalance in the process of river biology. Rainwater contributes the oxygen to the river by surface run-off or mixed directly to the river. Eventhough, the rainwater can increase the DO value, the present of bacteria during the surface run-off could reduce the oxygen by the decomposition of bacteria.

3) Turbidity

Turbidity refers to the clarity of water; water will high clarity represent the amount of suspended solid which harmful to the aquatic life. Heavy rain with stormwater could increase the level of turbidity by the ground-wash, sediment transportation, and other contaminants to the water. This situation also could distract the organism habits which need light due to the high clarity.

4) Nutrient Level (Nitrogen and Phosphorus)

The level of nutrient need to control even though its helping is growing the plants, if fail it can cause the algae production. Rainwater in the agriculture area or town, could bring fertiliser, animal dungs, and other substance that could help the nutrient of the river. The high amount of nutrient also can cause the eutrophication which effect to the oxygen level and kill the fish.

5) Conductivity

Conductivity quantifies water's capacity to transmit an electrical charge, influenced by the concentration of dissolved salts. Rainwater typically exhibits low conductivity; however, it can acquire minerals and contaminants from the atmosphere or soil prior to entering rivers. In regions next to industrial operations or urban runoff, precipitation can elevate river conductivity, signifying the presence of contaminants such as heavy metals or salts.

6) Temperature

Temperature influences numerous physical, chemical, and biological processes in rivers. Colder water typically possesses a higher concentration of dissolved oxygen, which is advantageous for aquatic organisms. Rainwater can lower river temperatures, particularly following extended dry spells, aiding in the restoration of ecological equilibrium. Nevertheless, if precipitation traverses a heated urban surface before to entering the river, it may elevate water temperatures, so exerting stress on aquatic organisms.

Rainwater serves two functions in affecting river water quality. It serves as a natural cleanser, refills waterways, dilutes contaminants, and revitalises the ecosystem. Conversely, it may also introduce pollutants, sediments, and surplus nutrients into the river, contingent upon the area it traverses. In metropolitan environments, rainwater can collect oil, heavy metals, and chemicals from roadways and industrial sites prior to flowing into rivers. In agricultural regions, it may transport pesticides and fertilisers, resulting in nutrient surplus. The frequency and severity of rainfall influence river quality. Moderate rainfall often sustains optimal river conditions, however excessive rainfall may lead to flooding and substantial runoff that introduces considerable pollution into rivers.

4. The Impact of Urbanisation and Industrialisation on Water Quality

Urbanisation denotes the expansion of urban areas and the transformation of natural environments, resulting in substantial alterations in water management and utilisation. Surface runoff is a direct consequence of urbanisation, as natural landscapes absorb precipitation, facilitating its infiltration into the soil and the replenishment of aquifers. Urban areas are characterised by impermeable surfaces like roads, pavements, and buildings, which inhibit water from penetrating the soil. Consequently,

precipitation rapidly drains, transporting contaminants including oil, heavy metals, debris, and chemicals into adjacent water bodies.

Stormwater pollution in metropolitan regions frequently utilises drainage systems that direct rainfall unprocessed into rivers, lakes, and seas. These runoffs can transport a mixture of contaminants, including motor oil, fertilisers, pesticides, and debris. Intense rainfall can inundate stormwater systems, resulting in combined sewer overflows, where untreated sewage amalgamates with stormwater and contaminates natural water bodies, severely compromising water quality. Modified rivers in urban environments frequently entail the alteration of natural watercourses, resulting in heightened erosion, sediment accumulation, diminished biodiversity, and decreased pollutant filtration, thereby rendering urban water bodies more susceptible to contamination. The urban heat island effect manifests when metropolitan regions exhibit higher temperatures than rural counterparts, elevating stormwater temperatures and placing stress on temperature-sensitive aquatic organisms.

Industrialisation, the extensive advancement of industry, has propelled economic expansion but has considerable environmental repercussions. Industrial processes frequently generate pollutants that can directly or indirectly impact water quality, particularly when restrictions and waste management procedures are insufficient. Toxic substances, including heavy metals, solvents, and synthetic compounds, are prevalent pollutants originating from the mining, manufacturing, and electronics sectors. Industrial wastewater from textile industries, paper mills, and food processing facilities frequently contains contaminants like organic waste, chemicals, colours, and nutrients. Inadequate treatment of these pollutants can lead to significant degradation of water quality. Thermal pollution, resulting from industrial activities that discharge heated water into rivers and lakes, disturbs local ecosystems by diminishing dissolved oxygen levels and modifying the habitats of fish and other creatures. Airborne pollution and acid precipitation are notable consequences of industrial emissions.

5. Monitoring Methods for Rainwater and River Water Quality

Water quality monitoring is crucial for ensuring the health of ecosystems and the safety of water sources for human use. It involves a range of methods that track physical, chemical, and biological parameters. These methods have become increasingly sophisticated over the years, combining on-site sensors, remote sensing technologies, and cutting-edge innovations like REE-based sensors to provide accurate, real-time data.

pH sensors measure the acidity or alkalinity of water, providing crucial data about the chemical balance of the water system. pH levels can fluctuate due to factors like pollution, acid rain, and industrial discharge. These sensors detect the concentration of hydrogen ions (H^+) in the water and convert this into an electrical signal, which is then translated into a pH reading. Continuous pH monitoring is essential in detecting shifts that could indicate pollution, acid rain, or the introduction of harmful substances.

Conductivity meters measure the water's ability to conduct electrical current, which is directly related to the concentration of dissolved salts, ions, and other chemicals. Higher conductivity levels in water often indicate pollution from agricultural runoff, industrial waste, or urban drainage. Turbidity sensors measure the cloudiness or haziness of water caused by suspended particles like silt, clay, organic matter, and microorganisms. High turbidity levels can indicate pollution, soil erosion, or excessive runoff following rainstorms.

Remote sensing technologies offer a broad, large-scale approach to water quality monitoring. They involve the use of satellites, drones, or aircraft to collect data on water bodies, providing valuable insights into parameters like temperature, turbidity, and chlorophyll levels. Remote sensing uses

electromagnetic radiation to capture images and data about the Earth's surface, allowing sensors mounted on satellites or drones to detect changes in water colour, temperature, and other indicators of water quality.

REE-based sensors are a cutting-edge technology that leverages the unique properties of rare earth elements (REEs) to monitor water quality. These elements, such as cerium (Ce), europium (Eu), and lanthanum (La), have distinct optical and electronic properties that make them highly sensitive to changes in the chemical composition of water. By measuring the intensity and wavelength of this light, the sensor can determine the presence and concentration of contaminants.

In conclusion, monitoring rainwater and river water quality requires a multifaceted approach that combines traditional tools like pH sensors, conductivity meters, and turbidity sensors with advanced technologies like remote sensing and REE-based sensors. By using these technologies, we can gain a deeper understanding of water systems and respond more effectively to changes, ensuring that water remains safe and healthy for both people and ecosystems.

7. Case Studies

When talking about the rainwater, river and pollution, several studies has been done year by year but, not much study were taking placing regarding the interrelation between these 3 entities. From the data processing by VOS Viewer, the study could justify the important or the study interrelation between rainwater and river to define the level of quality for the river which influence by the rainwater quality. Figure 1 shows the link by VOS Viewer the rainwater and river quality also the impact by the pollution if influence the quality of the river.

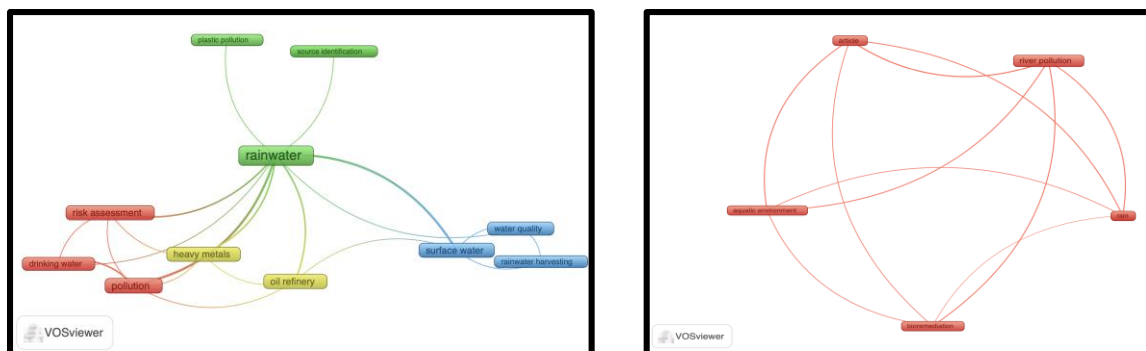


Figure 1. VOS viewer link shows the relationship of rainwater and river quality in Web of Science Journal and Scopus journal

The link of each element represents the impact full of rainwater and also the interrelation between rainwater to other element related to the river quality. Thus, this proof that every rainwater fall into the river could impact the quality of the river and also impact to the environment also the aquatic life.

8. Conclusion

This desktop study highlights the intricate relationship between rainwater and river water quality, emphasizing the role of rainwater as both a source of freshwater and a carrier of contaminants. The study underscores the need for continued monitoring of water quality using both traditional methods and advanced sensor technologies, including REE-based sensors. Furthermore, it advocates for integrated water resource management approaches that take into account the impacts of urbanization, industrialization, and climate change on water systems. Protecting river water quality is not only

essential for maintaining biodiversity and ecosystem health but also for ensuring the long-term sustainability of freshwater resources in the face of growing environmental pressures.

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