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Assessing Microbial Bioremediation and Ecological Health in Water Bodies of Southern Tamil Nadu

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Abstract

The Earth comprises three interrelated spheres: the Atmosphere, Hydrosphere, and Lithosphere. The Atmosphere, primarily nitrogen and oxygen, shields against harmful solar radiation. The Hydrosphere includes water bodies covering over two-thirds of the Earth's surface. The Lithosphere consists of soil, a crucial carbon reservoir supporting plant and microbial life. The Green Revolution has boosted food production through irrigation, improved seeds, fertilizers, and pesticides, but excessive chemical pesticide use has led to environmental pollution, affecting soil and water. Pesticides contaminate water through runoff, causing bioaccumulation and biomagnification, which disrupt aquatic ecosystems. Microbial bioremediation offers a sustainable solution, with bacteria degrading chemical residues and restoring balance. This study assesses the physicochemical characteristics of water and soil samples from Southern Tamil Nadu, India, isolates beneficial microbes, and evaluates their bioremediation and mosquito control potential. The findings will aid in environmental restoration and promote eco-friendly microbial pesticides, using statistical modeling and GIS techniques to understand water bodies' ecological health.

Keywords: Microbial bioremediation, Aquatic ecosystems, Soil and water quality

Introduction

Mother Earth, as part of the universe, consists of three spheres: the Atmosphere, Hydrosphere, and Lithosphere. The Atmosphere, primarily composed of gases like nitrogen and oxygen, protects life on Earth by acting as a shield against harmful cosmic radiation from the Sun. The Hydrosphere encompasses liquid water, covering more than two-thirds of the Earth's surface in oceans, lakes, rivers, and streams. Additionally, water exists underground as groundwater and in Polar Regions and high-altitude areas as snow and ice.

Soil acts as a main carbon reservoir in the biosphere. It undergoes continuous metamorphic changes and holds water, air, and nutrients essential for the growth of plants and microbes. These macronutrients in the soil are obtained through the weathering process of parent rocks. Soil contains nearly 17 micronutrients that support the growth of most phytoplankton and zooplankton. (Shukla *et al.*, 2018).

Soil acts as a purifier due to the presence of pores. Water in the capillary pores is useful for plant growth and is a key factor in the establishment of the biosphere on Earth. Excess water on the soil surface reaches water bodies through runoff, percolation, and filtration. Soil fertility and productivity depend on the physical, chemical, and biological characteristics of the soil. The increasing human population emphasizes the need to maximize agricultural production, leading to various agricultural revolutions. Notably, the Green Revolution was a period of technological advancements that significantly increased agricultural production.

The Green Revolution optimized yields by 44 percent from 1965 to 2010. Cereal and food grain production more than doubled in developing countries between 1961 and 1985. These production increases can be attributed to advancements in irrigation, seed development, fertilizers, and pesticides (David Blakeslee, *et al*., 2023). However, alongside the increased agricultural production, there was a significant rise in the use of chemical pesticides. The extensive use of inorganic fertilizers and pesticides by farmers to meet crop demands has led to pollution of the Earth's ecosystem.

Pesticides include insecticides, herbicides, acaricides, and fungicides, among others. Various types of inorganic pesticides are used, and most are probable causes of water pollution.

Pesticides like DDT (Dichlorodiphenyltrichloroethane), Parathion, and Malathion have been sprayed over time to manage pests. Heavy metals present in these pesticides pose major problems due to their persistent nature in the environment (Muhammad Shahid Nazir *et al.*, 2021).

Excessive inorganic pesticides runoff with rainwater and settle in stagnant water bodies (Gevao, 2000). These pesticides are also sprayed on crops to control pests at different stages, benefiting farmers but contaminating various parts of the crops and soil. Water bodies are primarily contaminated due to agricultural and urban runoff through pesticide leaching from soil or direct discharge of wastewater. Solid materials that settle down in water are also known as soil.

Pesticides interact with water through various mechanisms determined by their physical and chemical properties. All pesticides contain active ingredients mixed with inert compounds, such as solvents, to adjust their concentration. Consequently, water in agricultural systems can become contaminated by these active ingredients, fillers, or degradation intermediates (Louise Lodenkemper, 2021).

Penetration and dispersion are the primary ways pesticides transfer into soil and water. Pesticides degrade in soil and water, forming intermediate products. Degradation is a more intricate process for insoluble pesticides, while soluble ones degrade more readily in the environment. The stability of pesticides is linked to their half-life; persistent pesticides have longer half-lives and exert pressure on the environment over extended periods (Das SK, 2014).

Large quantities of agrochemicals are released into water, posing a threat to Earth's ecosystems. According to the Food and Agriculture Organization of the United Nations (FAO), irrigated agricultural land expanded significantly to about 320 million hectares by 2014. Over recent decades, the use of pesticides has increased, adversely affecting both surface and groundwater quality.

Aquatic ecosystems comprise phytoplankton and zooplankton, forming the foundation of the aquatic food web. Phytoplankton sustains zooplankton, which in turn supports organisms ranging from microscopic species to large marine animals like whales (Schwarzbauer, J. 2020). Microbes play vital roles in these ecosystems, transferring between soil and water through atmospheric washout and acting as essential inoculums. Soil and water host diverse microbial communities, including algae, bacteria (such as actinomycetes), fungi, and small amounts of viruses, adapting to both aerobic and anaerobic conditions.

Alongside rainwater, pesticide runoff into water bodies disrupts biological food chains and webs, promoting bioaccumulation and biomagnification processes (Tongo, I., *et al*., 2022; Rishikesh Chormare, Madhava Anil Kumar, 2022). Certain microbes, particularly bacteria, facilitate the bioremediation of these pesticides.

Microbial bioremediation is a biotechnological process aimed at environmental restoration. Bacteria, due to their natural ability to thrive in harsh conditions, are employed to degrade chemical residues. Researchers worldwide are discovering new bacterial strains with plasmid-linked degradation capabilities (Cornu, JY. *et al*., 2017; Srivastava, J., *et al*., 2014). Beneficial actinomycetes also possess bioremediation abilities.

Wetlands and water bodies serve as major breeding grounds for mosquitoes, which typically prefer laying eggs in nutrient-rich substrates. Synthetic pesticide applications to control mosquito populations pose risks to non-target organisms. Certain bacteria can effectively control mosquitoes, offering eco-friendly and target-specific alternatives to inorganic pesticides. Microbial pesticides derived from actinomycetes like *Bacillus thuringiensis* (Bt), *B. sphaericus* (Bs), and other microbes are reported as environmentally friendly substitutes for mosquito control (Rabia Tanvir *et al*., 2014; Saravanakumar *et al*., 2022).

Microbial studies vary by locality and season, with numerous mechanisms documented in literature for the degradation of synthetic pesticides. Despite challenges, microorganisms play a crucial role in pesticide biodegradation. This investigation focuses on studying microbes in selected water bodies and soil sediments affected by pesticides.

Objectives of the Study

The primary objectives of the study are as follows:

- Evaluate the physico-chemical characteristics of water and soil samples from the study area.

- Investigate the diversity of microbial populations in the collected samples.
- Isolate and identify actinomycetes from soil samples in the selected study area.
- Screen for pesticidal residues in the collected samples.
- Identify microbes capable of bioremediation and mosquito control.
- Assess the status of selected water bodies using statistical modelling and GIS techniques to analyze various characteristic features.

Materials and Methods

Methods adopted for analysis

- Physicochemical, biological, and nutrient parameters of water and soil will be determined during summer, pre-monsoon, post-monsoon, and winter seasons using standard methods outlined by The American Public Health Association (APHA, 2012).
- Pesticides will be extracted from different environmental samples using the Solid Phase Micro Extraction – Gas Chromatography Mass Spectrometric method (SPME – GCMS) as described by Adalberto Menezes Filho *et al.* (2010).
- Soil microbes and actinomycetes will be isolated from soil samples using the standard serial dilution method, following the procedures outlined by Valanarasu *et al*. (2009).
- The larvicidal toxicity bioassay will be conducted using World Health Organization (WHO) standard procedures, as detailed by Pathalam *et al.* (2017).
- Primary data will be analyzed using appropriate statistical tools.
- Collected data will be interpreted using GIS software for comprehensive spatial analysis and mapping.

Study Area

Surface water bodies at varying altitudes, including dams, reservoirs, and ponds, are selected as the sampling areas for this study. The research focuses on investigating changes in microbial load across different altitudes. Specifically, the study will be conducted at Suthamalli Dam, Thenkarai Pond, Manjalar Dam, and Shanmuganathi Reservoir in the southern districts of Tamil Nadu, India.

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Figure: 1.0. Study Area

Suthamalli dam (37 MSL)

Thenkarai pond (136 MSL)

Manjalar dam (311 MSL)

Shanmuganathi reservoir (419 MSL)

Suthamalli dam (37 Mean Sea Level (MSL)) – This reservoir is located in Thirunelveli district, Tamil Nadu state and it act as a main water resource for the farm land around the dam. Paddy, blackgram and Banana is the major crops cultivated around the reservoir. Suthamalli dam is one of the Thamirabarani river sub-basins. This river originates from the Agasthiyar / Koodam peak of Pothigai hills of the Western Ghats. Latitude 10.84542 °N and longitude 78.78655 °S.

Thenkarai pond (136 MSL) – This pond is connected with Vaigai river and polluted due to Thiruparamkundram pilgrims as well as various anthropogenic activities. This pond is the main irrigation water source for the agricultural lands. Paddy, Banana and fodder crops are cultivated by using this water. Fishing is carried out by the local fisherman in this area. Latitude 9.8907° N and longitude 78.0723° E

Manjalar dam (311 MSL) – This dam is located in Theni District, Tamil Nadu state and the dam has been constructed for the irrigation purposes. It is situated in downstream of Kodaikanal hills of Western Ghats and polluted by various means of anthropogenic activities. Latitude 10°11′44″N and longitude 77°38′01″E.

Shanmuganathi reservoir (419 MSL) - The Shanmuganathi Dam is constructed across the Shanmugha River close to Rayapanpatty, Theni district, Tamil Nadu. It supplies irrigation water for the dry lands of Pusarikoundanpatti, Appipatti, SukkangalPatti, Vellaiammalpuram, Odaipatti and Sepalakottai in Theni district. Pesticide residues around the Tea estates reach the reservoir through run off process. Latitude 10.4553° N and longitude 77.4909° E

Significance

The construction of water bodies serves crucial purposes such as drinking, agriculture, industry, and groundwater recharge. However, in recent years, these water bodies have faced contamination from various non-point pollution sources and anthropogenic activities.

The health of water bodies can be evaluated using a range of physico-chemical parameters. Assessing the beneficial microbial communities present can uncover new microbial species and their potential roles. These microbes can play a key role in bioremediation, aiding in the recovery of water bodies contaminated by pesticides.

Microbes also offer biological control of mosquito populations by consuming larvae and eggs, thereby reducing breeding rates. Analyzing the nature of water bodies allows classification into categories such as Eutrophic, Mesotrophic, or Oligotrophic, providing insights into their ecological status and informing conservation strategies.

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