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FUNDAMENTAL AND INNOVATIVE RESEARCH TECHNIQUES APPLIED ON WATER POLLUTION OF KAMLA RIVER

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ABSTRACT Selection of appropriate river water treatment methods is important for the restoration of river ecosystems. An in-depth review of Kamla river water treatment, fundamental and innovative technologies has been carried out in this study. Among the fundamental physical processes, aeration is an effective, sustainable and popular technique which increases microbial activity and degrades organic pollutants. Other techniques (water diversion, mechanical algae removal, hydraulic structures and dredging) are effective as well as cost intensive to river ecosystems. Chemical treatments are criticised for their short-term solution, high cost and potential for secondary pollution. Ecological based techniques are preferable due to their high economic, environmental and ecological benefits, their ease of maintenance and the fact that they are free from secondary pollution. Constructed wetlands, microbial dosing, ecological floating beds and biofilms technologies are the most widely applicable ecological techniques, although some variabilities are observed in their performances. Otherhands, some innovative ICT and Sensor Technologies are also applied by developed and developing countries, on river pollutants to get actual data and irradicate pollutants in best manner. Water quality data are collected mainly by manual field sampling, and recently real-time sensor monitoring has been increasingly applied for efficient data collection. However, real-time sensor monitoring still relies on only a few parameters, such as water level, velocity, temperature, conductivity, dissolved oxygen (DO), and pH. Although advanced sensing technologies, such as hyperspectral images (HSI), have been used for the areal monitoring of algal bloom, other water quality sensors for organic compounds, phosphorus (P), and nitrogen (N) still need to be further developed and improved for field applications. The utilization of information and communications technology (ICT) with sensor technology shows great potential for the monitoring, transmission, and management of field water-quality data and thus for developing effective water quality management.

KEYWORDS : Aeration, Dilution, Hydraulic, Flocculation, Precipitation, Bioremediation, Biofilms, Contact Oxidation, Membrane Bioreactor, Monitoring, Data Transmission, Electrochemical, Sensor, Optical.

INTRODUCTION

Water is one of the most important renewable resources. North Bihar is endowed with immense fresh water resources in the form of many river like Kamla, Bagmati, Koshi, Butahi-Balan, Kareh etc. Kamla is one of the major river in North Bihar. It drains and affects life of four districts namely Madhubani, Darbhanga, Saharsa and Khagaria. Jaynagar is one of the oldest and bordered town of India and Nepal which is situated on the bank of Kamla river. During the course of its flow through Madhubani, it receives all the domestic sewage of the town. There are three out of six cremation ghats (NH-104 bridge, Near Kali and old Durga Mandir) along the bank of the river which also add to the pollution load of the river water and much polluted by means of different 18 physico-chemical and microbiological parameters references done as per APHA (2005). Raised value of temperature, pH, Alkalinity, Turbidity, Conductivity, Hardness, Phosphate, Sulphate, Nitrate, Chloride, Calcium, Iron, TDS, BOD, COD, DO, Faecal coliform and Phytoplanktons at some points indicated the pollution of reverine ecosystem due to domestic and agricultural wastes. Due to high TDS, Turbidity and Faecal coliform, the river water of Kamla becomes contaminate and harms to aquatic life & agriculture.

Pollution of river water is one of the biggest environmental problems, particularly in developing and underdeveloped countries. River water is the source of water for drinking and for domestic, agricultural, commercial, industrial and recreation uses. However, river water pollution in some countries is so severe that it cannot be used at all. Furthermore, it causes the spread of water borne diseases in many developing countries, emits severe and intolerable odours and pollutes the air. Water quality management depends on the strict policy controls for discharge of solid waste, wastewater, stormwater and standards of treated or untreated wastewater, which requires cost and time for successful execution [1]. Therefore, water management plans must consider sustainable strategies and policies for the successful remediation of polluted water [2].

METHODOLOGY

By applying some fundamental and innovative techniques, Water of Kamla river must be renewed and become fit for aquatic life along with agricultural uses.

There are following fundamental techniques to obtaining concrete data and irradicate Physico-chemical and biological pollutants.

Physical Techniques

Mechanical Aeration Processes, Water transfer or Diversion and Dilution, Mechanical Algae Removal, Building Hydraulic Structures, Dredging River Sediment, etc

CHEMICAL TECHNIQUES

Flocculation, Precipitation, Oxidation, Algaecides, etc

BIOLOGICAL TECHNIQUES

Microbial Bioremediation, Biofilms, Contact Oxidation, Membrane Bioreactor Technology, Ecological Ponds, Plant Purification Treatment, Ecological Floating Beds, Constructed Wetlands, etc

There are several biological-ecological treatment technologies available in the literature, such as microbial bioremediation, biofilms, contact oxidation, membrane bioreactor technology, ecological ponds, plant purification treatment, ecological floating beds and constructed wetlands [1]. Polluted river water exhibits odour, turbidity, lack of water transparency, high concentrations of chemical oxygen demand (COD), biological oxygen demand (BOD) and organic and inorganic contaminants. Some studies have used the processes of microorganism, plant and aquatic animal-assisted bioremediation or biodegradation processes to destroy or decompose the organic chemical contaminants, absorb metals (inorganic contaminants) and completely remove the COD, BOD, odour, turbidity and organic and inorganic contaminants from river water.

These processes used both microbial dosing and in-situ microbial techniques. In-situ microbial techniques, which use native bacteria, are more environmentally sustainable and economically feasible. Consequently, in-situ microbial techniques are widely acceptable and applicable and have attracted more attention in wastewater treatment.

The most common in-situ microbial techniques used for the treatment of riverwater are the plant-assisted floating bed techniques and constructed wetlands. These techniques can naturally produce bacteria, fungi and fauna, which play important roles in biodegradation of organic contaminants in river water. Biological methods are more environment-friendly, self-sustaining and less expensive than the physical and chemical processes. However, the processes need an extended time, ranging from several months to years for microbial growth and, sometimes, different environmental factors such as temperature and rainfall affect their performance. Some of these technologies require high cost, labour and maintenance as well[3].

Table 1. Efficiency, advantages, and disadvantages of different physical/engineering-based treatment methods of river water.

TREATMENT/ TECHNIQUES	PROCESS/DE SCRIPTION	ADVANTAGES	DIS ADVANTAGES

ARTIFICIAL AERATION	Air flow into river water increases microbial diversity and degrades organic compounds in water	Effectively improve water quality, simple and easy to apply, sustainable and widely applicable	Cost intensive during operation and maintenance phase
WATER TRANSFER/DIVERSION	Mixing of clean water with polluted river water and dilution of pollution	Improve river water quality, water supply, river pollution control, promote self-purification process	Potential destruction of ecosystem, cost and labour intensive
MECHANICAL ALGAE REMOVAL	Removal of algae by mechanical process	Improve river water and sediment quality	Cost intensive during operation and maintenance phase
DREDGING RIVER SEDIMENT	Removal of polluted sediment by dredging machine	Improve sediment and river water environment	Potential increase of pollution, cost intensive mechanical process
BUILDING HYDRAULIC STRUCTURES	Irrigation weirs or infrastructure built on the river	Improve river water quality for irrigation purposes	Potential destruction of ecosystem health, cost intensive
RIVERBANK FILTRATION	Flow through riverbed and groundwater aquifer to the pumping wells	Remove organic and inorganic contaminants through natural filtration process	Slow process

Reference Air flow into river water increases Artificial aeration microbial diversity and degrades organic compounds in water Cost intensive during operation and Effectively improve water quality, simple and easy to apply, sustainable and widely applicable maintenance phase[4]. Water transfer/diversion Mixing of clean water with polluted river water and dilution of pollution Improve river water quality, water supply, river pollution control, promote self-purification process Potential destruction of ecosystem, cost and labour intensive. Mechanical algae removal Removal of algae by mechanical process Improve river water and sediment quality Cost intensive during operation and maintenance phase. Dredging river sediment Removal of polluted sediment by dredging machine Improve sediment and river water environment Potential increase of pollution, cost intensive mechanical process. Building hydraulic structures Irrigation weirs or infrastructure built on the river Improve river water quality for irrigation purposes Potential destruction of ecosystem health, cost intensive. Riverbank filtration Flow through riverbed and groundwater aquifer to the pumping wells Remove organic and inorganic contaminants through natural filtration process Slow process[5]. Ecological engineering-based techniques, such as plant purification treatment, ecological floating beds, artificial floating islands and constructed wetlands, have attracted the greatest attention due to their overall economic, environmental and ecological benefits, but these methods demonstrate variable performances to remediate polluted river water [6]. The remediation of river water is a critical process which needs the combination of engineering and ecological technologies for successful treatment of river water. Therefore, further research is needed to improve these remediation processes. The advantages and drawbacks of currently developed methods are to be comparatively discussed to find out the most effective, sustainable, economic and environment friendly processes. Overall, this review discussed the various single and hybrid techniques applied for the remediation of polluted river water along with their efficiencies, advantages and disadvantages. Finally, this review explored the most viable and sustainable techniques for the treatment of river water and how these techniques can be further improved to make them more cost effective and sustainable[7].

But now a days in developed and developing countries, the following ICT and Sensor Technologies are followed to detect and irradicate the river and ponds water pollution.

1. Sensing Technology for Water Quality Monitoring
1. 1A. General Sensor-Based Water Quality Monitoring Systems
   1B. Physical Monitoring Sensors
   1C. Chemical Monitoring Sensors
   1D. Optical Remote Sensors
1.2. Current Commercially Available Real-Time Monitoring Sensors
1.3. Electrochemical Detection of Algal Toxins
1.4. Consideration in Water Quality Monitoring Using Sensors
2. Technical Factors in Real-Time Monitoring
2.1. Data Transmission Systems
2.2. Wireless Sensor Technology
3. Advanced Data Analysis with Machine Learning for Water Quality Analysis
4. Future of ICT Research for Water Quality Monitoring

RESULTS AND DISCUSSION

The random disposal of treated and untreated solid and liquid wastes into water pollutes the receiving river water with nutrients, organic chemicals, metals and nanomaterials. There are different physical, chemical, biological, ecological and engineering methods available for the treatment of polluted river water. The most widely applied engineering and physical processes are aeration, water transfer, mechanical algae removal, building hydraulic structures and dredging river sediment. Aeration is an effective, sustainable and widely applicable technique that plays an important role in increasing the diversity of the microbial community and degrading organic chemicals in river water[7]. Despite the effective remediation of polluted river water, other engineering methods may cause the destruction of the river ecosystem. Therefore, physical engineering techniques should be applied in combination with biological and ecological engineering processes to enhance the ecological restoration process of rivers. Riverbank filtration is a natural, slow and self-sustainable process which removes organic and inorganic contaminants from river water without any adverse effects[9]. The microbial agents, ecological floating beds, constructed wetlands and biofilm reactor techniques use microorganisms and plant-based bioremediation processes to decompose organic chemicals and remove nutrients and metals from river water. Despite their variable purification performances, these methods have shown high economic, environmental and ecological benefits, have an ease of maintenance and are free from secondary pollution. These techniques combine physical, chemical, biological and ecological engineering processes for the effective removal of water pollutants and the restoration of the river ecosystem. Biofilm reactors are highly efficient at remediating polluted river water through the growth of microbial communities in biofilms. The efficiency and stability of the biofilm-based systems are dependent on water flow velocity, hydraulic loading rate, temperature, components of media and water depth. The gravel contact oxidation method is applicable to shallow creeks, but not to deep river water. The moving bed biofilm reactors show high efficiency in the removal of COD and organic matter[8]. The direct mixing of microbial agents with river water moderately removes NH_3-N, COD and TP, whereas engineering-based applications of microbial agents significantly degrades organic matter and removes COD, BOD and nutrients. However, their application should be monitored cautiously to avoid microbial contamination. Ecological floating bed techniques are more widely applicable for the treatment of river water. Water fluctuation, river waves and inundation do not affect their treatment performances. The appropriate selection of plant species is the key influential parameter for them. Inclusion of high capacity adsorbent materials in the matrix of floating mats enhances their contaminant removal efficiency. The hybrid, integrated, sequential and engineering-based floating bed wetlands can demonstrate the maximum water purification efficiency and overcome the drawbacks of single constructed floating beds or wetland. Aquatic animals have shown contradictory and moderate performances for the restoration of polluted river water. Therefore, this technique is not recommended for the treatment of river water[10].

2. Sensing Technology for Water Quality Monitoring
2.1. General Sensor-Based Water Quality Monitoring Syste

The assessment of water quality comprises physical, chemical, and biological indicators. Common. corresponding parameters include pH, electric conductivity (EC), dissolved oxygen (DO), turbidity, temperature, total organic content, total suspended solids (TSS), and nutrient concentrations such as nitrogen (N) and phosphorus (P), which represent the degree of contamination of water. In general, sensors detect stimuli from the environment, which are converted to signals (e.g., mV and pA) and stored in a data platform for further use [3]. A wireless water quality monitoring system comprises several steps: data collection; signal processing, such as noise control; data amplification and transmission; and data management, including a computing process. Geetha and Gouthami (2016) specified the three steps as follows: First, the field water quality data is collected steps: data collection; signal processing, such as noise control; data amplification and transmission; and data management, including a computing process[11].

2.1.1 Physical Monitoring Sensors

In situ sensors have been used for years to measure physical-based parameters, such as oxygen, pH, and CO2 in seawater; conductivity, depth, and temperature (CDT); and nephelometric turbidity units (NTU). Arrays of sensors are typically used together in automated systems, either deployed from a ship or on a mooring, as part of an observation system [11]

In Leigh et al.'s (2018) study of river water quality during high-flow events, in situ automated water quality sensors that contained NTU and CDT sensors were placed at three study sites. Sensors were placed inside flow cells on monitoring stations on the riverbank sides, allowing water to pump through the flow cell and for pressure-induction sensors to record NTU and electrical conductivity [12].

2.1.2. Chemical Monitoring Sensors

Electrochemical sensors and biosensors are also potentially viable methods of water quality monitoring. Commercially available CDT instruments use conductometric electrodes to measure salinity, Ag_2S electrodes to measure sulfur, and potentiometric methods to detect oxygen and nitrous oxide. The phosphate ion electrode is one of the most important parts of the sensing system, and it has been proposed to use a cobalt (Co)-based phosphate microelectrode because Co is a phosphate-sensitive electrode material.

2.1.3. Optical Remote Sensors

Remote observations provided by satellite sensors offer among the greatest spatial coverage at a specific time. The Moderate Resolution Imaging Spectroradiometer (MODIS) sensor was used to gain global coverage every 1–2 days, who notes that using ocean color to determine water turbidity and phytoplankton population (Chl-a) based on radiative transfer equations provides spatial coverage and an easy method to observe water quality patterns, but at the cost of limiting analyses of absolute concentrations and small-scale horizontal and vertical variability. In situ field sampling may be required to solve this issue.

2.2. Current Commercially Available Real-Time Monitoring Sensors

Real-time monitoring sensors are applied in various fields, such as drinking-water supply systems, river and lake management, and water resource distribution [13]. Exemplary water quality parameters measured with sensing technology. For proper management of water quality, pHvalue, DO concentration, electric conductivity (EC), and temperature are among the most common parameters that provide useful information. For example, abrupt changes in the pH value, EC, or DO concentration suggest an input of toxic chemicals, whereas abrupt changes in the temperature affect the aquatic ecosystem

2.3. Electrochemical Detection of Algal Toxins

For the sensors to be coated with immobilized MC-LR molecules, the carbon working electrode is functionalized by electrochemical oxidation in an alkaline solution (e.g., 1.16 V vs. Ag/AgCl for 1 min in NaOH), to produce oxygen-containing functional groups on the carbon surface that are subsequently used as anchoring sites for the covalent immobilization of MC-LR to the surface via cross-linkers.

2.4. Consideration in Water Quality Monitoring Using Sensors

According to Adamo et al. (2014), three major challenges of water quality monitoring using in situ probes are the manuallabor andtimerequiredforsampling, findingoptimaltimeintervals to go out to water bodies, and the availability of funds from agencies responsible for monitoring. Remote sensors and wireless communication systems can lead to real-time monitoring technologies by providing rapid hydrologic changes that can implicate alarm events, such as algal blooms and f looding [13]. The composition of the waters in question can also lead to difficulties in the analysis. For example, Chl-a has no homogenous distribution in water, but spatial disorganization can indicate events occurring on ascale of single-digit to tens of meters. Chl-a is an important indicator of waterbody trophic status, but analysis of spatial patterns can be complicated due to biological, physical, and chemical factors [13]. Thus, it is important to consider sensors that are tunable to ecological proxies (e.g., Chl-a sensitive sensorsto detect signs of HAB development, or TSS-sensitive probes capable of monitoring resuspension events that can provide traceable steps for pathogen detection or anthropogenic disturbance).

The current status of remote sensors for water quality measurement is not suited for all situations. For complete spatial and temporal, as well as accurate assessments, remote sensing is still to be integrated with other methodologies, such as field sampling and in situ sensor technology. A study completed by Chen-et-al. (2018) recognizes these concern sand examples of the concept of water quality monitoring in a smart city [14]. This pilot project was developed to integrate Wireless Sensor Network (WSN)-based solutions with smart city infrastructure for improving monitoring methodology.

3. Technical Factors in Real-Time Monitoring

3.1. Data Transmission Systems

Recently, the applications of Information and Communication Technologies (ICTs) have become increasingly useful tools for managing water sectors. The ICTs for water quality monitoring include in situ sensing systems, data cloud, and machine learning components. Vijayakumar and Ramya (2015) emphasized the importance of ICT (e.g., ubiquitous computing and cloud computing) for the real-time monitoring and management of the water quality. Ubiquitous environments are already increasingly used in practical applications [15]. Cloud computing enables the storage and analysis of massive data, without using local computer hardware. The easy, remote assessment of the recorded data through a websiteis one of the important advantages.

3.2. Wireless Sensor Technology

While multiple insitu online sensors are used for real-time monitoring in drinking-water treatment plants, for the monitoring of big natural-water systems, wired sensors are widely used. However, a wireless sensor network has a clear advantage for the real-time detection of massive data with relatively low costs compared with those of traditional monitoring methods. The representative wireless network technologies applicable to water quality monitoring are Wi-Fi, ZigBee, and Bluetooth. Wi-Fi is one of the most commonly used technologies for the data transmission between devices based on wireless local area networks, according to the Institute of Electrical and Electronics Engineers 802.11 Standard.

More recently, Di Gennaro et al. (2019) suggested a prototype water quality monitoring system using SigFox that includes units of pH, turbidity and temperature sensors, and a global positioning system (GPS) module, which also has the advantage of being low-cost and having a low power consumption [17]. These prototype LPWA studies suggest a possible advance of water quality monitoring paradigm with low cost and wide range in the near future.

4. Advanced Data Analysis with Machine Learning for Water Quality Analysis

The use of web-based data storing and processing with the Internet has recently increased with the usage of sensor data. Various technologies related to the Internet of Things (IoTs) are applied for remote sensing and the management of measured data. The easy accessibility and use of open-source programming languages (e.g., R or Python) enable advanced analysis of data with high data processing technologies, such as machine learning. Multiple linear regression is one of the commonly used methods for water quality data analysis.

Advanced deep-learning algorithms are increasingly used for the analysis of water quality data. For example, Solanki et al. (2015) used a deep-belief network (DBN), a class of deep neural networks with multiple hidden layers, for the prediction of the DO concentration, pH value, and turbidity in a watershed [16]. Muharemi et al. (2019) used various machine learning models (e.g., ANNs, SVMs, and LSTMs) for the analysis of time series data and suggested machine learning for the detection of anomalies in the water quality [18].

5. Future of ICT Research for Water Quality Monitoring

The advanced ICT has increasingly been used for water quality monitoring and provides useful information for the proper management of water resources. There are possible future research fields to improve the applicability of ICT for water quality monitoring of a wide range of areas. Firstly, the compatibility of measurement frequencies between different water quality parameters in in situ real-time data collection is essential for effective management of water quality for future cities.Thus, observation of higher frequency data and properpretreatment of the massive data (e.g., interpolation) to minimize internal error or missing points of data are essential for improving the practicability of the advanced data analysis technologies.

Secondly, areal-based monitoring technology, such as HSI sensor, can be further developed for the collection of representative data in a remote and wide watershed, overcoming the limitation of point-based monitoring. For example, algal concentrations are often unevenly distributed within the surface of the water body, and thus point-based monitoring may not be able to provide accurate data for the degree of algal blooms. The areal-based monitoring using an HSI sensor can provide a more accurate distribution of algal concentrations [18].

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