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A STUDY ON TRADITIONAL WATER QUALITY ASSESSMENT METHODS

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ABSTRACT

Water quality has been damaged in countries that have an abundance of water resources, but also by the rapid industrialization, urbanisation, and population increase. They often have significant pollution levels in the rivers. Industrial regions, sewage, agriculture, and animal husbandry are the three most prevalent anthropogenic activities. Water pollution can also result from natural calamities like floods and the illegal disposal of chemical waste. Water pollution is dangerous to human's health, as well as the environment, society, economy, and wildlife. Hence, water quality examination is crucial for reducing challenges associated or caused by water pollution. This study delved into the review of different traditional water quality examination methods with a view to identify the most advantageous one. The traditional water quality examination methods are single-factor examination method, nemerow pollution index, comprehensive pollution index method, principle component analysis, fuzzy comprehensive evaluation method, and water quality identification index. The merits and demerites of all these methods were examined, and it was discovered that water quality identification index will be more plausible; however, it is costly.

Keywords: Water, Water Pollution, Water Quality, Assessment Methods, Traditional Water Examination

1.0 INTRODUCTION

The decline in water quality is a major global challenge that keeps getting worse. Governments, businesses, non-profit organisations, and the general public should all take this harmful issue seriously (Gayathri et al., 2017). This is because water makes up 70% of the globe and more than 60% of the human body (Taru & Karwankar, 2017).

Water that is clean and safe is essential for drinking, domestic use, industry, and health, as dirty water and inadequate sanitation can spread diseases like cholera, diarrhoea, hepatitis, skin infections, typhoid, and other health hazards (Hu et al., 2016; Hrudey et al., 2013). It is essential to note that wastes generated from homes, businesses, farms, and public transportation do contaminate water (Rahmat et al., 2016). As a result, the health of citizens who make use of polluted water is negatively effected (Adeniran, Ilugbami & Oyeniran, 2024; Rahmat et al., 2016). Water is utilised for washing, drinking, farming, and industrial processes. Aquaculture ecosystems and human health are at risk from contaminated water, thus it must be safe and clean.

It is mostly caused by cities rising and their populations increasing, and it is endangering drinking water supplies, human and ecological health, and future economic growth (Morse & Wollheim 2014). Because surface waterways are easily accessible for wastewater disposal, they are particularly susceptible to contamination (Singh et al., 2014). Both natural processes (such as soil erosion and chemical weathering) and human inputs (such as agricultural runoff and the discharge of industrial and municipal wastewater) contribute to the deprivation of water quality (Shin et al. 2013). Sustainable water resource use in terms of ecosystem health and socioeconomic development which, more crucially, establishes the groundwork for the prevention and management of surface water pollution requires a practical and trustworthy evaluation of water quality (Adeniran, Ilugbami & Oyeniran, 2024; Shrestha & Kazama, 2017).

To successfully tackle issues surrounding water quality, it is essential to first provide a detailed examination of the water quality challenge and its root causes (National Research Council, 2011). A large body of research has examined quality state and deterioration state of water using various evaluation techniques during the last ten years. For instance, Huang et al. (2020) demonstrated that the main river channel of the Qiantang River had superior water quality than its tributaries using a fuzzy comprehensive examination and multivariate statistical approach. Similarly, Massoud (2022) used the water quality index approach to assess the degree of water contamination in the Damour River (southern Lebanon). The findings showed that human activity along the Damour River was affecting the river's water quality (National Research Council, 2011).

Similarly, Xu (2015) introduced the complete water quality identification index (CWQII), a novel instrument for the overall evaluation of surface water quality. The water quality in Taizi River was assessed by Fu et al. (2022) in China using the CWQII technique; the findings showed that the water quality declined between 2019 and 2022. The CWQII values of Honghu Lake (China) were also measured by Ban et al. (2022), and it was revealed that CWQII increased between 2011 and 2015 and maintained a balance between 2016 and 2021. This indicated that the water quality had progressively improved since 2016 as a result of water protection measurements conducted by the local government in 2014. This study entails the review of different traditional water quality examination methods with a view to identify the most advantageous one.

2.0 LITERATURE REVIEW

2.1 Review of traditional methods used for water pollution monitoring

Water quality has been damaged in countries that have an abundance of water resources, but also by the rapid industrialization, urbanisation, and population increase. They often have significant pollution levels in the rivers. Industrial regions, sewage, agriculture, and animal husbandry are the three most prevalent anthropogenic activities (Devi, 2021). Water pollution can also result from natural calamities like floods and the illegal disposal of chemical waste (See et al., 2017).

Water pollution is an evil that may harm people's health, as well as the environment, society, economy, and wildlife. Water quality monitoring is crucial for reducing problems with water pollution, and the best way to offer early evaluations of toxins in water is through the use of a water quality monitoring system (Khatri et al., 2020).

The government typically monitors water quality, with assistance from the business sector, in many industrialised nations such as the United States, the United Kingdom, Malaysia, Germany, Japan, China, and others. This includes weekly inspections of groundwater, rivers, and lakes (Shrestha & Kazama, 2017). Some of these nations will face a water crisis by 2025 if the significance of good water management is not sufficiently understood (Rahman, 2021). Because 79% of people in ten countries in Southeast Asia and the Pacific use groundwater, it is one of the most important sources of drinking water for households. However, there are common concerns about pollution from improper sanitation, which can result in shortages during the dry season, among other things (Carrard et al., 2019).

Furthermore, physical, chemical, and biological qualities can be used to identify pollutants that cause water contamination. Chemical parameters include the following: pH level, ammonia, salinity, hardness, organic compounds, metals, dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), and so on (Singh et al., 2021). Among their biological characteristics are viruses, bacteria, and algae. Turbidity, temperature, colour, taste, odour, suspended particles, and metals are examples of physical attributes. To assess whether water is suitable for human consumption and ecosystem health, it is crucial to consider certain attributes of water quality (Nurul-Ruhayu, An & Khairun, 2022; Razman et al., 2018).

Water quality index (WQI) is measured through different water quality parameters. The few among the commonly used parameters are discussed below:

a) **pH of water:** This specifies how acidic or alkaline the water is. Between 0 and 6 is the acidic range, whereas between 8 and 14 is the alkaline range. The most suitable pH range is 6.5–8.5. Electrometry and pH electrodes are used to measure the pH of water. It is significantly correlated with electrical conductivity, total hardness, sulphates and total suspended solids (Bhandari & Nayal, 2018).
b) **Turbidity of water:** This is the measurement of nonfilterable, divided solids in the water. Additionally, this can obstruct the process of water purification. Nephelometric Turbidity units are the most used unit of measurement (NTUs). A turbidimeter or nephelometer is used to measure it. It strongly correlate with electrical conductivity, sulfates, total dissolved solids, total hardness, and chemical oxygen demand. (Verma & Singh, 2022).
c) **Temperature:** One of the most crucial factors that significantly affects aquatic life is this one. It also effects the amount of dissolved oxygen and gas transfer rates. It might change some of the components' concentration or shape. Most measurements are made in Celsius. In the field, thermometry or a thermistor is used to measure it. It has a weak correlation with pH and strongly correlate with electrical conductivity (Khatoon et al., 2013).
d) **Chloride (Cl):** It is found naturally in water, and while too much of it typically has no negative effects on humans, if the concentration rises to more than 250 mg/l, the taste of the water becomes more saline and might be detrimental to agricultural practices. It is mostly measured in milligrams per litre (mg/l) via titration (Ali & Qamar, 2015).
e) **Electrical conductivity (EC):** This shows that there is a chance that the water will conduct electricity. In terms of the water quality, it has no immediate benefit. However, it is more beneficial in terms of the ionic constituent of the water, which in turn controls the hardness, alkalinity, and part of the dissolved solids (Khatoon et al., 2013).
f) **Dissolved oxygen (DO):** This demonstrates how soluble oxygen is in water. Most of the oxygen in water is either taken up from the atmosphere or created by photosynthesis.

Aquatic life is greatly effected by it. Electrometric meters and Winkler titration are the most often used techniques for measuring it. It is highly correlated with electrical conductivity, biological oxygen consumption, and sulfates, according to the EPA (2013).

g) **Total suspended solids (TSS):** This is the volume of solid debris, both organic and inorganic, that is still floating in the water. Because of the increased TSS, the water is more likely to absorb light, which raises the water's temperature and reduces its capacity to contain oxygen. It has a major effect on aquatic life. It is measured in mg/l using the gravimetric method, which involves filtering and drying at a certain temperature. It has a strong relationship with both total dissolved solids and pH (Verma & Singh, 2022).

h) **Total dissolved solids (TDS):** It is the quantity of soluble organic and inorganic substances that are still present in the water. It has a strong correlation with salinity, and as it rises, the water becomes more salinized. It is quantified in mg/l using the gravimetric technique, which involves drying the sample at a certain temperature after filtration (Bhandari & Nayal, 2018).

i) Chemical oxygen demand (COD): This is the quantity of oxygen used in the oxidation of existing inorganic material and the breakdown of organic stuff. It is strongly connected with turbidity, chlorides, electrical conductivity, total hardness, and total dissolved solids. Like BOD, it is a significant indicator of the state of water quality. It is determined in milligrams per litre (mg/l) by micro digestion, colourimetry, and reflux distillation with acid potassium dichromate followed by titrimetric analysis (Verma & Singh, 2022).

j) Total coliform (TC): Faecal coliforms and other non-fecal bacteria that are comparable to them are primarily found in soil. Total coliforms are associated with faecal coliforms and indicate the potential presence of harmful microorganisms. The number of organisms/100 ml is assessed using the membrane filtering method and the multiple tube approach, which is the most likely way (Cabral & Marques, 2016).

2.2 Comparison of various water quality monitoring methods

Water distribution systems and treatment plants each have specialised instruments for monitoring water quality to identify impurities and determine if the water is fit for human consumption. Over the past few decades, a great deal of research has been done on sensing and monitoring analyses to produce reliable and effective approaches with the least amount of energy and running expenses. Pollution detection tools still have some limitations. Thus, it is necessary to update the present water quality examinations. A Raspberry Pi-based hardware platform was used in the water monitoring system that (Khatri et al., 2019) suggested. The system made use of fuzzy logic for decision-making and a Python framework to create a graphical user interface (GUI). In addition, another method (Ragavan, 2016) employed wireless sensor networks to continually check the water quality in distant locations.

Three components make up the wireless sensor network (WSN) system: a distant monitoring station, a database station, and data monitoring nodes. MATLAB was utilised by the software design to communicate with the remote monitoring station's hardware (Taru & Karwankar, 2017; Bernama, 2020).

Numerous applications, including the health monitoring sector, smart buildings, location, estimate and prediction, and fault detection, might benefit from the system's implementation (Bernama, 2020). The approach may, however, present some challenges, such as the possibility of highly complicated data being acquired, which might result in costly and unpredictable outcomes. Water quality characteristics were detected using a variety of water quality monitoring sensors, and an Arduino board was utilised to interface with the sensors and provide an effective presentation of the data (Goi, 2020). Every sensor's reading value was obtained using Arduino in this approach, and the Raspberry Pi received the data via the Internet (Goi, 2020).

Another improvement was made by Taru & Karwankar (2017), who created a system that interfaced with LabVIEW and Arduino to improve data-collecting performance. The system was simple to install, use, and adaptable. Khatri et al. (2019) established the use of fuzzy logic in decision-making, developing the fuzzy method in MATLAB and calculating the water quality index using a Python framework. In addition, optical methods based on light propagation theory are critical for determining the exact locations and times of sewage contaminations in real-time field settings with low costs, a simple procedure, and excellent accuracy outcomes.

By employing optical spectroscopy, one may leverage statistical relationships between the optical characteristics of water samples, such as reflection, refraction, fluorescence, and absorbance spectra, to calibrate and find sewage pollution. For example, vibrational spectroscopy is an optical method that has been employed recently. Infrared (IR) and Raman spectrometers are the devices used in vibrational spectroscopy (Adeniran et al., 2024). Two popular vibration spectroscopy methods for chemical and biological investigation are infrared (IR) and Raman Spectroscopy, which provide quick and easy non-destructive evaluation of several parameters at once (Cozzolino, 2022). Because it is so reliant on the physical condition of the sample, this method is frequently used to analyse the liquid and gas phases of water.

To preserve water quality, a fluorescence spectroscopy approach is also necessary for the quick and accurate identification of three common pathogenic bacteria, including K. pneumonia, S. aureus, and E. coli (Du et al., 2022). A UV laser was utilised as an excitation light source to stimulate bacterial dilutions in LIF (laser-induced fluorescence) experiments, and fluorescence emission spectra were simultaneously recorded using a spectrometer. The analysis of several gradients of bacteria concentration in this study demonstrated a strong linear correlation between the concentration of bacteria and the height of the fluorescence peak. When compared to active E. coli, inactive E. coli does not affect the fluorescence peak location.

Because dormant bacteria constantly germinate, there are differences in the salt levels required for consideration. This system incorporated an ESP 32 Wi-Fi module and a Wi-Fi access point (AP) and displayed the results on the ThingSpeak IoT platform. It was said that data on the EC level was obtained from the EC sensor to determine the salinity level. High-sensitivity sensors were employed to deliver dependable and accurate data. From the perspective of smart sensor aquaculture, the method offers easier setup and upkeep, a more economical option, simultaneous on-site monitoring, and overall very dependable operation.

2.3 Traditional Methods

Water quality may be observed using traditional methods. It is predicated on on-site sample collection and laboratory-performed chemical, physical, and microbiological examination. Labour- and money-intensive, this approach (Khatri et al., 2019). Modern approaches can generate output in real time, whereas conventional procedures often yield results after a few days. Central Water Commission operates as an example of a conventional technique. Within the processing and distribution system, certain places are used to gather water samples, which are then examined in state-of-the-art laboratories. Water quality indicators including pH, turbidity, and dissolved oxygen were assessed using lab-based equipment after samples of raw, filtered, and treated water were analysed (Barabde & Danve, 2015).

Errors resulting from field sampling and miscalibrated equipment might cast doubt on results. Aside from that, the sampling method's intricate procedure might make it extremely time-consuming. Since human energy is required to complete tasks, the conventional method's drawbacks include the system's lack of continuity and reliability as well as its potentially extremely low testing frequency (Barabde & Danve, 2015). A competent individual typically completes the analytical tasks with high accuracy parameter detection outcomes. In addition, the cost of maintaining laboratory facilities is high (Paepae et al., 2021). Traditional laboratory techniques are more expensive, time-consuming, and need chemical reagents; they are also unable to provide measurements in real time (Adeniran et al., 2024). As a result, the study does not include ongoing system monitoring.

2.4 Comparing traditional methods with modern methods

A comparative survey was conducted by Mercy (2018) on the traditional and modern methods for water quality analysis. Since modern techniques can give output data and analyse the characteristics of water quality in real time, they offer more advantages than traditional methods. Immediate detection of low water quality allows for prompt remediation of unwanted materials in the water. Traditional approaches have the potential to result in delays and human mistakes during procedures (Mahajan & Shahane, 2021). The traditional methods primarily involve the collection and tracking of water samples, with laboratory analysis conducted (Mercy, 2018). When preparing samples in the lab, mistakes might happen.

Mercy (2018) determined water quality parameters in conventional ways using the titration technique. Since the titration procedure cannot be completed in a single day, it takes time to complete. Using sodium hydroxide, the titration technique is used to measure the amount of carbon dioxide in a solution. When there is an exchange of ions between the H+ ions in the emf and the swollen layer, pH may be measured via potentiometric analysis. When the glass electrode was submerged in water, the outer layer of the glass bulb became hydrated and the swelling layer developed (Mercy, 2018). The technique for monitoring water quality was created utilising wireless sensor nodes. Ten parameters in all were monitored inside node boxes as part of the system, which was linked to the wireless sensor node via WiFi.

The farmers might get data through an access point. The concerning pattern was used if an issue arose (Mercy, 2018). The manual approach to monitoring water quality in aquaculture is labour-intensive and time-consuming, and it cannot yield consistent findings like the current method, which uses sensors to check water quality parameters more rapidly and with better results. The constituents of the water sample may alter as a result of the laborious and complicated setup, producing data that is less useful for tracking water quality (Pasika &

Gandla, 2020). Thus, adding additional sensors can increase the system's ability to monitor water quality, which in turn can assist authorities in taking prompt action to improve the water quality.

2.5 Methods of Monitoring Water Quality in Various Countries

Numerous techniques for examining water quality have lately been developed in numerous nations. For instance, Burberry et al. (2021) developed an nitrate monitoring station optical sensor which is automated. Based on leaching from agricultural land in New Zealand, the results indicated that majority of the variance in nitrate had been detected at or near the water edge, with yearly occurrence between August and November (Burberry et al., 2021). In addition, to address problems with regional water quality examination, (Li et al., 2021) developed a novel multistage decision support system with a complicated multi-criteria decision-making (MCDM).

There were three steps to the system. The initial phase included of 21 distinct water quality indicators, excluding temperature indicators, and processed vast amounts of monitoring data using the probabilistic linguistic term set (PLTS) approach. Regression-based decision-making trial and evaluation laboratory (DEMATEL), for example, provided relative weight for the second and third stages that took into account the interplay of indicators. Single-factor weight was then balanced to make a combined weight. To offer evaluation results for the last stage, a new LTS measure was presented together with an extension of the fuzzy approach. The water quality status of Shanghai was then examined using the suggested methodology (Li et al., 2021).

An extensive study of Lake Palic's water quality was conducted by Horvat et al. (2021) in Serbia. Measurements of the water quality were taken for nine years, from 2021 to 2019, as part of the analysis. Water quality parameters were determined by fitting a model using multivariate regression (Horvat et al., 2021). The multivariate analytic approach was also utilised by Hasan et al. (2020) to assess the groundwater quality in Bangladesh's northeast. The method employed multivariate analysis to analyse the water quality of particular pumps and to provide significant findings that were not possible with a superficial review of the data.

To meet drinking water requirements, Khatri et al. (2020) measured the pollution levels in the Sabarmati River in Gujarat, India, and evaluated the levels of many indicators. Water quality metrics including pH, turbidity, total dissolved solids (TDS), total alkalinity, total hardness, chloride, ammoniacal nitrogen, dissolved oxygen, conductivity, and biochemical oxygen demand (BOD) were employed by the system. The correlation analysis matrix demonstrated that these water quality characteristics had an effect on the fundamental ionic chemistry, especially pH, EC, TDS, K+, Na+, Mg2+, and SO42− (Hasan et al., 2020; Khatri et al., 2020).

Moreover, heavy metal contaminations were investigated in the water quality of the River Netravati, another river in India (Gayathri et al., 2017). The methodology employed was akin to that of Horvat et al. and Hasan et al., who employed multivariate analysis. In 2019, during the pre-monsoon season, water and sediment samples were gathered from places in the Netravati River basin. Following this, hydrogeochemical properties were examined. The hydrogeochemical characteristics of water play a crucial role in identifying the kinds that are used for irrigation, industry, and residential usage. Environmental indicators and multivariate approaches were used to analyse metal contaminations. The state of the water quality is indicated by the use of environmental indicators.

The full WQI approach was used to assess the river's water quality. Ten sample stations' worth of water quality indicators were used to compute WQI. The examination of overall concentrations and distributions of metal demonstrated that sediments had a little heavy metal contamination, likely as a result of increased urbanisation and agricultural practices that altered the hydrological regimes of rivers. Aquatic life is seriously threatened by exposure to pollutants, since it can alter metabolic processes and the structure of river communities (Gayathri et al., 2017).

3.0 FINDINGS

3.1 Merits and demerit of traditional methods

The merits and demerites of the traditional methods are appraised as follows to help understand the method:

1. Single-factor examination method: The maximum membership grade concept guides the determination of this approach (Ban, Wu & Pan, 2014). This technique only takes into account the largest contributing factor or the most contaminated water quality parameter; as a result, all other factors were not taken into account in the evaluation results (Li & Zhang, 2020).

Demerit: Mei, Liao, and Zhu (2014) note that dissolved oxygen, chemical and biological oxygen demand, and numerous other metrics were also severely compromised. Therefore, when several contaminants are contributing, this technique does not properly portray the total water quality (Wang & Wang, 2021), and it is challenging to compare with water quality evaluations from other places that may have distinct pollution challenges (Massoud, 2022).

2. Nemerow pollution index: This method considers the average contribution of all components as well as the dominating parameter (Yang, Mei & Liu, 2013; Lu, Mei & Zhang, 2021).

Demerit: According to Simeonov, Stratis, and Samara (2013), this approach has a tendency to overemphasise the effect of the maximal evaluation factor, or the most important polluting component. Accordingly, when one examination factor's index value is much greater than the others, the comprehensive score will be raised (Liu, Heilig & Chen, 2017). Therefore, there is a chance that the examination's findings won't match the state of the water's quality overall (Singh, Malik & Mohan, 2014).

3. Comprehensive pollution index method: Hope, Parker, and Peake (2022) state that this technique yields a thorough examination of the water quality.

Demerit: Yang, Mei, and Liu (2013) argue that the approach's foundation is the idea that every examination criteria contributes equally to the overall quality of the water, but this idea isn't necessarily realistic in real-world situations (Dierk & Michael, 2018; Houser & Richardson, 2020). One specific issue with water quality monitoring is the difficulty in interpreting the vast array of observed variables (Houser & Richardson, 2020).

4. Principle component analysis: This method facilitates the interpretation of intricate data matrices, hence improving comprehension of the water quality (Bu, Tan & Li, 2020; Morse & Wollheim, 2014). This approach offers effective separation for higher water quality categories in addition to taking water quality into account (Lu & Lo, 2012).

Demerit: According to Helena, Pardo, and Vega (2000), two limitations of principle component analysis are its inability to analyse nonlinear data and its disregard for the degree of data dispersion. As a result, according to Shin, Artigas, and Hobble (2013), principal component analysis may not have excellent accuracy and dependability.

5. Fuzzy comprehensive evaluation method: This method can objectively depict the overall state of water quality and describe the fuzzy nature of classification boundaries for water quality (Holloway, Dahlgren, & Hansen, 1998). (Khanna, 2000).

Demerit: Extreme water quality values are overemphasised (Chen, Chang & Shaw, 2015). In this instance, some data is lost, and it's not always evident what the weighting factor's scientific foundation is (Shin, Artigas & Hobble, 2013).

6. Water quality identification index: When it comes to the thorough field examination of water quality conditions, the water quality identification index is well regarded for its dependability and remarkable accuracy (Cheng, Zhou & Zhu, 2017; Phung, Huang & Rutherford, 2015). According to Dalal et al. (2020), it is the greatest option for figuring out how the water quality in highly contaminated areas is doing. According to Xu (2015) and Bu et al. (2020), the benefits include:

a) Evaluating general water quality using a set of examination items;
b) Comparing general water quality with the same classification and successfully classifying water quality conditions as inferior; and
c) Depicting water quality and assessing the entire water quality conditions both qualitatively and quantitatively.

The only demerit is that it is costly.

4.0 CONCLUSION

This study delved into the review of different traditional water quality examination methods with a view to identify the most advantageous one. The traditional water quality examination methods are single-factor examination method, nemerow pollution indexc, comprehensive pollution index method, principle component analysis, fuzzy comprehensive evaluation method, and water quality identification index. The merits and demerites of all these methods were examined, and it was discovered that water quality identification index will be more plausible; nonetheless, it is costly.

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