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A REVIEW ON MICROBIAL CONTAMINATION DETECTION IN WATER RESOURCES

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ABSTRACT:

Because of the risk of contamination by pathogenic bacteria, protozoa, or viruses, microbial pollution in aquatic environments is one of the most important concerns with regard to the sanitary state of water bodies that are used for the provision of drinking water, for recreational activities, and for the harvesting of seafood. These water bodies are used for these purposes. At drinking water treatment facilities, turbidity measurements are often used to conduct microbial contamination monitoring. These measures are used to evaluate the risk of microbiological contamination. Recent research has shown that there is a substantial association between the risk of endemic gastroenteritis and the presence of microbial contamination. However, since the presence of colloids in water causes interferences with the nephelometric response, the applicability of turbidimetry may be restricted to a certain extent. Therefore, there is a need for an indicator that is more pertinent, easy, and quick for the identification of microbial contamination in water, particularly in light of climate change, which has resulted in a rise in the frequency of extreme rainfall events. This review focuses, on the one hand, on the sources, fate, and behaviour of microorganisms in water as well as factors that influence the presence of pathogens as well as factors that influence transportation and mobilisation, and, on the other hand, on the existing optical methods that are used for monitoring microbiological risks. In conclusion, this article suggests several innovative approaches to future study.

Keywords: *optical methods; heavy rainfall; colloids; turbidity; pathogens*

INTRODUCTION:

Within the framework of international legislation, the pollution of water bodies by organic micropollutants is a topic that is of continuing interest and is continually being looked into. Even though several studies have shown a consistent and significant association between heavy rainfall events and waterborne disease outbreaks [2,3] and the consequences of climate change [4], microbial contamination is rarely considered, despite the fact that it is the root cause of numerous outbreaks of gastrointestinal diseases and public health concerns. [1] This is the case despite the fact that microbial contamination is at the origin of numerous public health concerns. A recent review of reviews [5] brought to light the fact that there are not enough research done on the subject of waterborne infections and how they are connected to severe occurrences (such as droughts and floods). Even if there is a legal framework in place, microbiological quality is often a cause of impairment when it comes to the compliance of drinking water supply [6], in particular for small scale water systems (SSWS) [7,8] and private water supplies [9–11]. [6] [7,8] [9–11] In addition, it is known that severe weather circumstances, such as climate change, may cause a rise in the amount of microbial contamination in the water, which calls for more investigations using a systematic approach [12,13]. The goals of monitoring consist of immediately addressing the sources of contamination, making use of simple and speedy indications, but concentrating their attention primarily on metrics like faecal bacteria (E. coli or Enterococci). The detection limitations of currently used techniques prevent researchers from looking into enteric viruses, despite the fact that these viruses play a significant role in waterborne infections [14,15]. Therefore, even in situations when microbiological water quality criteria are met, the percentage of endemic cases of waterborne acute gastroenteritis (AGE) may range anywhere from 0 to 40 percent [16,17], and this doesn't even take into account the smallest supply water systems (Analytical methods have been created over a long period of time with the purpose of improving human understanding about the nature and origins of microorganisms. In more recent times, a variety of studies have shown the significance of an ecological approach (the function that sediment and aquatic plants play) [18–23]. In spite of the fact that polymerase chain reaction (PCR) is often utilised in microbial source tracing, its tailored approach for certain microbial genera or species has prevented it from finding broad application in microbial monitoring systems [24,25]. The MST techniques that have been suggested for use in the identification of the source of faecal contamination have received a lot of documentation in published works [21,26–30]. In addition to these approaches and the traditional, standardised bacterial culture, there are a few more that may be used. These include methods that are based on the exploitation of the optical characteristics of water. The optical effects of microorganisms, which are often absorption and light diffusion, may provide a justification for the interest in optical approaches for the detection of microorganisms. Microorganisms are frequently adsorbed on colloids or particles. The effect of the interaction between light and matter can be used to detect bacteria or viruses either as free particles or as particles attached to organo-mineral complexes that are capable of modifying the optical properties of surfaces. This can be done either when the bacteria or viruses are free or when they are attached.

SOURCES, FATE AND BEHAVIOR OF MICROORGANISMS IN WATER:

The microbiological contamination of water is often of a faecal origin, and the source of the contamination may be people (water sewage treatment facilities, combined sewage overflow (CSO), or non-collective sewage systems), domesticated animals (manure spreading, pit stock overflow), or wildlife. The outputs of water treatment facilities, decontamination stations, hospitals, and businesses that are regarded to be point sources are the primary causes of microbial contamination of natural aquatic resources. Other possible point sources include: It is widely proven that there is a correlation between the concentrations of diseases and urban activity (e.g., [31,32]). On the other hand, it is possible to take into consideration dispersed sources such as slurry, manure, and the application of sludge. The contamination level, the persistence of pathogens in water bodies, biological reservoirs (including aquatic plants and sediments), and the capacity of pathogens to be transported are some of the factors that determine the abundance and significance of pathogens in water [33]. Other factors include the ability of pathogens to be transported. The land use management methods, as well as the size of the watershed, are additional factors that impact the microorganisms' ability to live [34–36]. Streams that run through regions that are either partially or completely covered with meadows are more likely to be polluted, as stated by George et al. [37], in comparison to streams that travel through woods and agricultural areas.

FATE IN SEDIMENTS AND IN SUBMERGED AQUATIC VEGETATION:

Microorganisms may be found in significant numbers in sediments as well as in submerged aquatic vegetation (SAV) [18,30,38]. For instance, Badgley et al. [18] demonstrated that SAV included much greater mean densities of Enterococci than sediments, which, in turn, contained higher densities than water. This was the case when comparing SAV to sediments and water. The high Enterococci concentrations seen in SAV are mostly attributable to the increased availability of nutrients, in addition to the protection they get from UV light. There may be ten times as many viruses in sediments as there are in water [33]. Garzio-Hadzick et al. [39] conducted research on the microorganisms that were able to survive in a variety of sediment types, each of which had its own unique particle size and amount of organic carbon. According to the findings of the researchers, the life of infections may be prolonged by sediments that have a high organic carbon content and tiny particle size. The researchers Chandran and colleagues [40] came to the conclusion that sediments might operate as a reservoir for harmful bacteria and provide a potential risk to human health due to the possibility of resuspension and subsequent ingestion during recreational activities. Granulometric distribution of particles has a vital function in the survival of microorganisms, and it also plays an important role in the transportation of these organisms during high flow events.

Alterations in hydrometeorological conditions, such as severe rainfalls, which are anticipated to become more frequent as a result of climate change, are another factor that might affect the behaviour of microorganisms [12]. Therefore, bacteria that are normally associated with sediments or SAV are returned to suspension, which may result in pollution of the water [18,33]. Cho et al. conducted research on the re-suspension of sediments either during or immediately after rainstorm events in order to explore the behaviour of E. coli in relation to the various bottom sediment textures of three streams during artificially induced high-flow events. A model for the transmission of bacteria was suggested; however, further study was required to determine which sediment qualities impact which parameters of streambed E. coli are discharged into the water column and how these parameters are affected.

TRANSPORT AND FATE OF MICROORGANISMS:

The relationships that exist between microorganisms and sediments not only affect the bacteria' ability to survive, but also the features of their transit. In addition, the destiny and transportation of faecal bacteria are intimately connected to the mechanisms that regulate the transportation of sediment [38]. Attachment to mineral surfaces and subsequent inactivation are two factors that have a significant impact on the spread of viruses that are associated with particles. This adsorption is capable of being undone in the presence of certain additional environmental variables, such as changes in pH. Soupir and Mostaghimi conducted research to investigate how microbes divide themselves during travel along overland flow paths, focusing on how they move between the freely floating and particle attached phases. Only 4.8 percent of E. coli and 13 percent of Enterococci were found to be associated with particles when rainfall simulations were carried out on large-scale field plots. These simulations revealed that the majority of E. coli and Enterococci are transported from the fresh manure source in an unattached state. When there is just a thin layer of vegetation covering an area, the percentage of adherent E. coli or Enterococci is less than 3 percent on average. E. coli appeared to be attached predominantly to small particles (63.3 m) in a laboratory-scale model system developed to investigate the transport mechanisms of E. coli in overland flow across saturated soils. C. perfringens spores were associated with particles size in the range of

45.5–63.3 m. The system was developed to investigate the transport mechanisms of E. coli in overland flow across saturated soils. This granulometric distribution of the related particles has significant impacts on the retention of microorganisms that are brought about by settling and transfer into sediments. In their research, Abudalo et al. and Searcy et al. came to the conclusion that the environmental impact of protozoan parasites is closely related to their extended survival in different climatic conditions and disinfection processes, as well as to their capacity to interact with other organic or nonorganic particles. This latter occurrence determines their survival, as well as their ability to be transported, retained (by settling), and/or released as they make their way from land to sea.

INFLUENCE OF HYDROMETEOROLOGICAL CONDITIONS:

The circumstances of the hydrologic and climatic systems have a significant impact on the dissemination of microorganisms. During times of heavy precipitation, combined sewage overflows (CSOs) and runoffs from agricultural land are more likely to contaminate surface water, leading to an increase in the presence of microbes [33,58]. Rainfall increases both the amount of suspended matter and the level of faecal contamination in small streams [37], with faecal coliforms mostly being adsorbed on the particles of the suspended matter. Rainfall events may also raise the human enteric virus load in natural waterways that have been contaminated by CSOs and stormwater, which can lead to an increased risk of gastroenteritis associated with recreational activities or the ingestion of shellfish [59]. This risk has been analysed using quantitative microbial risk assessment, which revealed that norovirus is the most common cause of swimming-related gastroenteritis [60]. Heavy rains can also lead to flooding in catchment areas, which is considered to be an unquestionable indicator of the possibility of contamination by aquatic pathogens [61,62]. Heavy rainfall can also lead to an increase in the water's turbidity, which can make it difficult to see objects in the water. Several prospective epidemiological investigations in France have revealed that groundwater impacted by surface water might be the source of gastrointestinal diseases on an endemic level [61,63], particularly during rainfall events in karstic environments. These research have proved this to be the case.

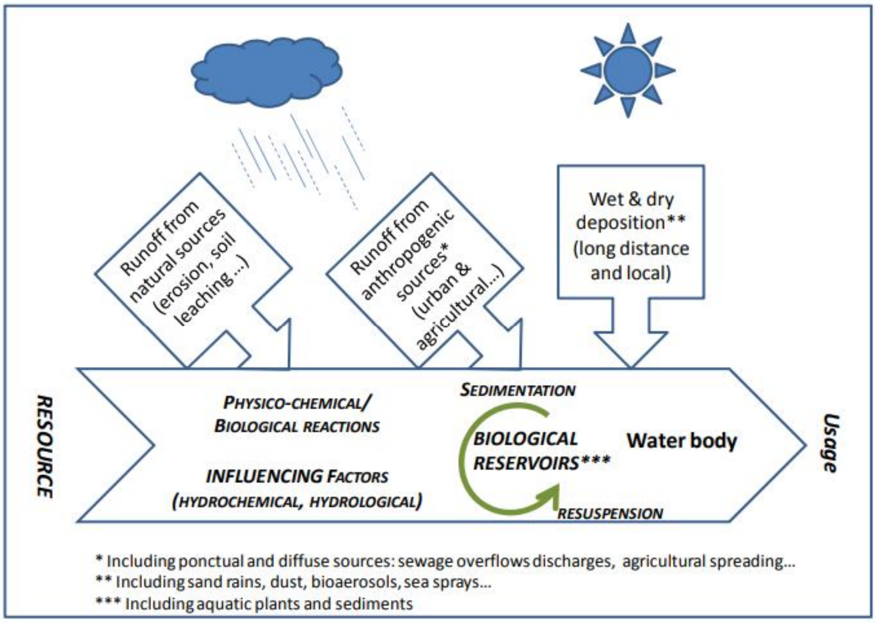

Figure 1. Schematic synthesis of source and fate of allochtonous microorganisms in water

The fluctuating temperature of the water is another factor that contributes to the hydrodynamic dispersal of microorganisms. During the summer in climatically moderate regions, lakes are often stratified (with warmer water at the surface). Heavy precipitation or storms may cause destratification by changing the convectional motions of particles in the atmosphere that carry microorganisms and bringing them closer to the surface. Wyer et al. [40] conducted research not too long ago in which they evaluated the fluctuation of faecal markers in four streams when there was a mild rainfall. They proved, with the use of a technique called microbial source tracing (MST), that the time it takes for the transfer to occur may range anywhere from minutes to hours, depending on the hydrological conditions and the features of the locations. Studies that are pertinent to this topic are included in Table 1, which deals with pathogen interactions with particulate and colloidal phases in the aquatic compartment. In conclusion, the diagram in figure 1 presents a proposed schematic of the origin and ultimate destination of allochtonous bacteria in water. The production of drinking water and the widespread use of recreational waterways by the general public both contribute to an increase in the human demand on the resource. From the time of sedimentation until the time of resuspension, the biological reservoirs are subjected, on the one hand, to the physicochemical and biological processes that occur in water bodies, and, on the other hand, to the hydrochemical and hydrological variables that occur in water bodies. In addition, depending on the climatic change, the runoffs from natural and human sources that are deemed to be external are classified as either punctual or diffuse contributions.

CONCLUSION:

This review has shown that our understanding of the methods by which pathogens are transported is incomplete, despite the fact that the part played by particles and colloids is reasonably extensively documented. In addition, there is a shortage of technologies (indices, sensors) that enable for on-site detection of microbial contamination and dynamic exchanges of pathogens into various phases, such as soluble, colloidal, and particulate forms. In regard to the first argument, the enhancement of the optical responses that are now supplied by turbidimetry might be an intriguing option to detect dangerous circumstances caused by water microbiological contamination. In point of fact, the relevance of the turbidity measurement is restricted due to the fact that nephelometric measurements are reliant on the presence of colloids, which might cause the findings to be inaccurate. All of these research needs must be considered at fair value because, in addition to the impact on population health, the importance of cost management of waterborne diseases such as acute gastroenteritis cannot be denied. Therefore, fair value consideration must be given to all of these research needs. The reduction of costs, which may be accomplished by improved forecasting of the hygienic deterioration of the quality of natural water supplies, is consequently an essential economic problem. When viewed from a scientific perspective, the most important issue will be how to supplement the primary indication of exposure, which is the turbidity measurement, with other metrics that are more precise, in particular hydrological circumstances. In order to solve this problem, a team of experts from several fields, including hydrologists, chemists, microbiologists, water treatment managers, and epidemiologists, will need to collaborate.

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