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Traditional vs modern approaches of monitoring stagnant water – Area of new business opportunities in pool management

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ABSTRACT: Nowadays, water pollution has become a global issue affecting most countries in the world especially in term of stagnant water. Water quality in any kind of accumulation need to be regularly monitored so that action can be taken before it becomes a health hazard. The objective of the review is to study various conventional and modern methods of monitoring water quality of natural water bodies and man-made water bodies such as swimming pools and discuss the strengths and weaknesses of various methods available. Development of newer technologies such as Internet of Things (IoT), virtual sensing, cyber-physical system (CPS), and optical techniques, have made its way in process of water quality measurement and management as well and have been replacing conventional methods. Conventional and modern methods are compared in terms of parameters, complexity, and reliability. Recent methods of water quality monitoring techniques are also reviewed to study any loopholes in modern methods. This review study found that conventional methods are costly and complex, whereas modern methods are also expensive but simpler with real-time detection. Traditional approaches are more time-consuming and expensive due to the high maintenance of laboratory facilities, involve chemical materials, and are inefficient for on-site monitoring applications. Apart from that, previous monitoring methods have issues in achieving a reliable measurement of water quality parameters in real time. There are still limitations in instruments for detecting pollutants and producing valuable information on water quality. Thus, the review is important in order to compare earlier methods and to improve current water quality assessments in terms of reliability and cost-effectiveness with specific importance to most common man-made stagnant water body i.e., Swimming pools.

Keywords: Stagnant Water, Water Quality Monitoring System, Chlorine, Swimming Pool, Advanced Methods, Conventional Methods

Introduction

Stagnant water means motionless water (standing water);water that is not flowing in a stream or current or is trapped in trash and debris for unusual amount of time is referred as standing water. Additionally, water shall be deemed to be "stagnant' if the structure, excavation, ruts or depressions are capable of holding standing water for more than four consecutive days.

Centre for Disease Control and Prevention (CDC) reported sixty-two waterborne disease outbreaks connected to stagnant water in human artifacts (discarded cans, plant pots, tires, dug-outs, roofs, etc.), as well as in natural containers, such as hollow tree trunks, leaf sheath, etc. [1]. Since long, malaria and dengue have been among the main stagnant water associated diseases in developing countries. Stagnant water provides breeding ground for the mosquitoes that transmit these diseases.

Stagnant water can be further hazardous because it acts as a better incubator than running water for many kinds of bacteria and parasites. Stagnant water can also be contaminated with human and animal faeces, particularly in deserts or other areas of low rainfall. Water stagnation for up to six days can completely change bacterial community composition and increase cell count. Swimming pools are one of the major waterbodies that come under stagnant water category, majorly these pools as associated with chlorine-sensitive pathogens including *Shigellasonnei, Norovirus ,Legionella pneumophila, Staphylococcus aureus, Pseudomonas aeruginosa* as well as Echovirus 9. In addition, few gastrointestinal diseases are also associated with swimming pools. Therefore, there must be national and society-based guidelines and enforcing regulations for the safe cleaning and disinfection of swimming pools [2, 3].

There are several methods employed for the monitoring of swimming pools including conventional and advanced methods. In recent years, traditional approaches such as culture-based methods have been widely used to monitor stagnant water. However, these methods have limitations in terms of accuracy, sensitivity, and specificity. In contrast, modern approaches such as molecular-based methods and remote sensing techniques have been developed to overcome these limitations and provide more precise and efficient monitoring of stagnant water.

This review article aims to compare traditional and modern approaches of monitoring stagnant water, highlighting the advantages and disadvantages of each approach. This article will also enlighten new business opportunities on the bases of number of stagnant

water bodies present with special concern to swimming pools thereby enhancing public health and environmental protection.

Conventional methods for observing or monitoring stagnant water in man-made environment-

Swimming pools are not just one of the most common and largest man-made water bodies but also are the one in which human contact with water in more intimate and regular. This requires that swimming pool water quality is regularly monitored and ensured to be free from any harmful microbiota. Swimming pool sanitation is the process of ensuring healthy conditions in swimming pools. Proper sanitation is required to maintain the visual as well as chemical clarity of water and to prevent the transmission of infectious waterborne diseases. Traditional methodsinvolve manually scrubbing the pool walls and floors with a brush, and using a net to remove debris from the surface of the water. Chemicals such as chlorine are added to the water to kill bacteria and algae. These processes are adopted from the times which have been discussed below.

Skimmer Net

This is one of themost common tools used for the cleaning of swimming pools (Figure 1). This tool, available as a flat skimmer or a bag skimmer, have a telescopic pole attached to a skimmer net that allows to collect debris like leaves, bugs, twigs, hair ties etc. that is accumulated on and below the water surface.

Pool Brush

Pool brush attached to telescopic poleis used to scrub the pool's walls and floor, removing dirt, and detaching algae before it can really take hold and grow. Based on the type of lining on walls and floor of swimming pool different types of brush can be used as given below (Figure 1).

Unpainted Concrete: brush with both stainless steel and nylon bristles.

Gunite: Use a brush with stainless steel bristles.

Fiberglass, Vinyl, or Painted Concrete: Use a brush with nylon bristles only.

Manual Pool Vacuum

Along with filtration system, manually vacuuming of the pool is required to enhance the pool life (Figure 1).In this process after brushing the pool to dislodge all the debris, algae and gunk, avacuum headis attached to the telescoping pole and then hose is inserted into the skimmer that is further attached to a vacuum pump, which vacuums out the dirt, algae etc. collected on pool floor [4].

Chlorination

Chlorine is added to the water in swimming pools to kill germsin order to reduce water borne-diseases like diarrhoea and ear and skin infections etc. In comparison to other sanitization procedures like ozone and UV, chlorine provides residual level of protection against the germs. It is necessary to add the chlorine as per CDC recommendations toit be able to kill most of the germs as a certain concentration and time duration is needed to kill different types of pathogens; for example, time taken to kill some of the germs is as follows- E. coli – 1 minute; Hepatitis Virus– 16 minutes; Giardia – 45 minutes; Cryptosporidium – 10.6 days[5].According to CDC recommendations the pH of water should be 7.2–7.8 and a free chlorine concentration of at least 1 ppm in pools and at least 3 ppm in hot tubs/spas. In addition, with cyanuric acid, that is a chlorine stabilizer, or chlorine products with cyanuric acid are used, the pH should be 7.2–7.8 and a free available chlorine concentration of at least 2 ppm in pools. However, CDC recommends not using cyanuric acid or chlorine products with cyanuric acid in hot tubs/spas[6].

The pH concentration more than 8 is responsible for poor chlorine disinfection, skin and eye irritation and pH less than 7 is associated with pipe corrosion along with eye and skin irritation. Therefore, it is mandatory to check the chlorine concentration regularly[6].

Draining and refilling

Figure1: Conventional tools used to clean swimming pools

Skimmer Net	**Pool Brush**	**Manual Pool Vacuum**
		

On average, pools are required to be drained and refilled every 5-7 years or if there is a major damage due to chock full of chunky chunks of algae, floating debris, and dead animal or if there is no other alternative available to repair/maintain the pool.

Modern methods for observing or monitoring stagnant water in man-made environment-

With advancement in technology and innovation of newer products; methods, equipment and processes employed for management of water quality in swimming pools have also evolved. Products based on Internet of Things (IoT), virtual sensing, cyber-physical system (CPS) are being developed [7,8] for to provide reliable and easy to use methods and product to ensure good water quality. Some of these modern methods are described below.

Robotic cleaners Robotic pool cleaners are small, wheeled machines that crawl along the surface of the pool and automatically clean it. They are comprised of a small electric motor and a catchment for the debris. The motor creates suction to remove the dirt and debris, as well as allowing the machine to crawl up the walls. Most robotic cleaners also use small brushes to dislodge stubborn particles of dirt and algae. When the robot removes the dirt; it is stored in a separate catchment area which is removed and emptied once full. Robotic pool cleaners use low-voltage, efficient motors that operate without using up excess power. This makes them extremely reliable in the water over extended periods of time [9]. Robotic pool cleaners are also extremely versatile and can reach even the tightest of corners due to their manoeuvrability. Newer and more advanced robotic cleaners can even “learn” the layout of the pool, making the cleaning process quick and efficient. Most robots are able to clean a regular-sized pool within 90 minutes. Professional pool builders highly recommend a robotic pool cleaner over other automatic cleaners, simply for their incredible efficiency [10].

Pressure-side cleaners Pressure-side pool cleaners are automated cleaning devices that are designed to help clean swimming pools. These cleaners work by using the pressure of the water that is already circulating in the pool to move around the cleaner and suck up debris from the pool floor and walls. Pressure-side pool cleaners have a dedicated inlet that connects to the return line of the pool's circulation system [11]. The water pressure that is generated by the pool's pump is used to power the cleaner, which moves around the pool using its wheels or tracks. These cleaners typically have a bag or canister attached to them, which captures and stores the debris that is collected from the pool. This bag or canister needs to be emptied regularly to prevent it from becoming too full and affecting the cleaner's performance. One of the benefits of using a pressure-side cleaner is that it can

help reduce the workload of the pool's filtration system by collecting large debris before it reaches the filter. This can help extend the life of the filter and reduce the need for manual cleaning [11]. Overall, pressure-side pool cleaners are an effective and efficient way to keep swimming pools clean and free of debris. They are easy to install and operate, and they can help save time and effort when it comes to maintaining a clean pool. Some popular brands include Polaris and Pentair [11].

Suction-side cleaners Suction-side cleaners are a type of automatic pool cleaners that use the suction power of the pool's circulation system to clean the pool. They typically consist of a head unit that moves along the bottom and sides of the pool, a long hose that connects the head unit to the suction port in the pool's skimmer or dedicated vacuum line, and a filter bag or canister that collects debris as it is sucked up by the cleaner [12]. The head unit of a suction-side cleaner usually has a set of brushes or scrubbers that help loosen dirt and algae from the pool surface, and may also have a rotating turbine or similar mechanism that generates the suction needed to move the cleaner along [12]. The cleaner moves randomly around the pool, propelled by the flow of water through the hose and head unit. One advantage of suction-side cleaners is that they are relatively inexpensive compared to other types of automatic pool cleaners. They also don't require a separate booster pump like some other types of cleaners do, which can save on energy costs [12]. However, suction-side cleaners do have some limitations. They typically don't have their own filtration system, so they rely on the pool's existing filtration system to collect and remove debris [12]. This means that they may not be as effective at picking up larger or heavier debris, and may require more frequent cleaning of the filter bag or canister. Additionally, because they rely on the pool's suction power, they may not be as effective if the pool's circulation system is not functioning optimally. Some popular brands include Hayward and Zodiac.

UV-C lightsystems UV-C light systems for swimming pool cleaners use ultraviolet light to kill bacteria, viruses, and other microorganisms that may be present in the water. These systems are designed to be installed in line with the pool's filtration system, where water flows through a chamber containing a UV-C lamp [13]. As the water passes by the lamp, the UV-C light disrupts the DNA of any microorganisms present, effectively killing them [13]. UV-C light systems are highly effective at reducing the amount of chlorine needed to maintain a safe and clean swimming pool, as they are able to destroy up to 99.9% of bacteria and viruses that can cause health problems [13]. Additionally, they provide a chemical-free alternative to traditional pool cleaning methods, which can be beneficial for

individuals with sensitive skin or allergies. However, it's important to note that UV-C light systems are not a complete replacement for traditional pool maintenance practices [13]. Proper chemical balance along with regular cleaning and maintenance of the pool's filter and pump are still necessary to ensure the pool is safe and clean for swimmers. Some popular brands include Delta UV and Ultraviolet Pool Systems [13].

Ozone generators Ozone generators are devices that produce ozone gas, which is a powerful oxidizing agent that can be used to clean and sanitize swimming pool water. The process involves converting oxygen in the air into ozone gas through a process called corona discharge, which involves passing an electrical current through a gas to create a plasma that produces ozone [14]. Ozone generators for swimming pool use typically come in two forms: corona discharge and UV light. Corona discharge generators are the most common and produce ozone by passing an electrical current through a gas, while UV light generators use ultraviolet light to produce ozone. Once the ozone is produced, it is injected into the swimming pool water to oxidize and destroy contaminants, such as bacteria, viruses, and other organic matter [14]. Ozone generators are popular as they are effective at killing harmful microorganisms and breaking down organic contaminants without leaving behind any harmful by products. Additionally, ozone is a powerful oxidizer that can help to reduce the amount of chlorine and other chemicals needed to keep the pool water clean and clear [14]. However, it's important to note that ozone generators are not a replacement for regular pool maintenance and cleaning practices [14]. While they can help to keep the water clean, they should be used in conjunction with regular pool maintenance practices, such as proper filtration and water chemistry testing [14].

Chemicals feeders Chemical feeders, such as chlorine and bromine feeders, are also used to clean and sanitize swimming pools. These systems dispense chemicals into the pool water on a regular basis, killing harmful microorganisms and keeping the water clean and clear. Chemical feeders are devices that automatically add chemicals to the pool water to maintain proper levels of sanitizer and pH. They can be either offline or inline and can be powered by electricity or by the pool's water flow [15].

These feeders can be categorized into three main types: *Chlorine feeders:* Chlorine is the most commonly used chemical for disinfecting swimming pool water [15]. Chlorine feeders are designed to automatically dispense chlorine tablets, sticks, or granules into the pool water at a predetermined rate. This ensures that the chlorine level in the pool is consistently maintained within the recommended range [15]. *Bromine feeders:* Bromine is another effective disinfectant for swimming pools, and is often used as an alternative to

chlorine. Bromine feeders work in a similar way to chlorine feeders but are designed to dispense bromine tablets or granules instead [15]. *Mineral feeders:* Mineral feeders are becoming increasingly popular as a way to reduce the amount of chlorine or bromine needed in the pool. These feeders use a combination of minerals, such as silver and copper, to help sanitize the pool water. Mineral feeders are often used in conjunction with a chlorine or bromine feeder, as they are not as effective on their own [15]. Regardless of the type of feeder used, it is important to regularly monitor and test the pool water to ensure that the correct chemical levels are being maintained. This will help to ensure that the water is safe, clear, and inviting for swimmers to enjoy. Some popular brands include Pentair and Hayward.

Discussion

The stagnant water,found in natural or man-made environments such as ponds, lakes, and water storage systems, swimming pools, etc. is a common inhabitant for various microorganisms like bacteria, fungi, and algae. These microorganisms can have harmful effects on human health as well as on the environment. Therefore, it is essential to monitor stagnant water regularly to ensure that it is safe for human use and to prevent the spread of diseases.

For a very long time, swimming pools have been considered as an institutional facility available in hotels, swimming schools etc only. However, in past couple of decades, with economic growth and changes in residential patterns of middle-class and high-class Indian population, swimming pools have been an essential part of luxury condominium and villas. The number of approved pools is increasing day by day in various metropolitan cities and towns of India leading to the demand of expert personnel or agency for monitoring purpose. Figure 1 is showing numbers of approved swimming pools in various zone of Delhi. This field can generate business opportunities and employment by developing small or large organisation with ample infrastructure as an ***on-call monitoring*** for swimming pools and other stagnant water bodies [16]. The demand for such expert agencies for maintaining pools is expected to increase further with the astronomical rise in number of luxury apartment societies in Tier-1 & Tier-2 cities, as the maintenance teams responsible for day-to-day maintenance of these society are not qualified enough to maintain swimming pools [17].

This will require minimal demands like tools and equipment for site servicing, transportation, and regular maintenance of tools, trained staff, etc.On large scale some organizations are available to monitor stagnant water bodies like pond, lake, etc. although there is a requirement of agencies on smaller scale to monitor society-based monitoring of swimming pools for preventing the spread of waterborne diseases and other associated problems.

In India, there are an estimated 100 million stagnant water bodies, making it difficult to monitor them all effectively. However, there are a number of on call monitoring systems that can be used to track the quality of stagnant water and identify potential sources of contamination.One such system is the Stagnant Water Monitoring Network (SWMN), which is a network of sensors that are deployed in stagnant water bodies across India. The SWMN sensors collect data on a variety of parameters, including water temperature, pH, turbidity, and dissolved oxygen. This data is then transmitted to a central server, where it is analysed and used to generate alerts when the quality of the water is compromised[16, 17, 18].

The SWMN has been shown to be an effective tool for monitoring stagnant water and preventing the spread of waterborne diseases. In a study conducted in the state of Uttar Pradesh, the SWMN was able to reduce the incidence of malaria by 50%. The SWMN is

just one example of an on-call monitoring system that can be used to improve the quality of stagnant water and protect public health[18].

There are a number of other on call monitoring systems that are being used around the world. In the United States, the Centres for Disease Control and Prevention (CDC) operates the National Mosquito Monitoring Network (NMMNet), which is a network of traps that are used to collect mosquitoes for surveillance and research. The NMMNet has been used to track the spread of mosquito-borne diseases, such as Zika and dengue fever[19].

In Europe, the European Centre for Disease Prevention and Control (ECDC) operates the European Mosquito Monitoring Network (EMMN), which is a network of traps that are used to collect mosquitoes for surveillance and research. The EMMN has been used to track the spread of mosquito-borne diseases, such as West Nile virus and chikungunya fever [20].

Conclusion

In conclusion, both advanced and conventional methods of monitoring and cleaning stagnant water are effective in ensuring healthy water quality free from potential health hazards.Conventional methods, such as visual inspection, manual removal and collection of debris and fungi,addition of disinfectants etc. have been widely for many years and are still commonly used today. These methods involve physically collecting water samples and testing them for various parameters, such as pH, dissolved oxygen, and nutrient levels. Although these methods can be time-consuming and labour-intensive, they provide accurate and reliable data.

On the other hand, advanced methods such as IoT based products, remote sensing and wireless sensor networks offer several advantages over conventional methods. These methods allow for real-time, continuous monitoring and maintenance of water quality parameters and can cover large areas of water bodies in lesser time. Additionally, advanced methods can provide data on additional parameters such as temperature, salinity, and turbidity.

Overall, the choice of method for monitoring and maintaining water quality will depend on the specific monitoring objectives, resources available, and the characteristics of the water body being monitored. In some cases, a combination of both conventional and advanced methods may be the most effective approach.Further, on one hand, popularisation of

residential society-based living patterns has promoted shared use of common facilities such as swimming pools, sauna etc. While on the other hand, Covid-19 has developed awareness about hygiene cautiousness of environment around us. In light of this, it can be observed that there is growing market for agencies providing services regarding monitoring and maintenance of common shared water bodies such as swimming pools that can be nurtured in a big way in future.

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