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Review Article

Detection of contaminants in water supply: A review on state-of-the-art monitoring technologies and their applications

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ABSTRACT

Water monitoring technologies are widely used for contaminants detection in wide variety of water ecology applications such as water treatment plant and water distribution system. A tremendous amount of research has been conducted over the past decades to develop robust and efficient techniques of contaminants detection with minimum operating cost and energy. Recent developments in spectroscopic techniques and biosensor approach have improved the detection sensitivities, quantitatively and qualitatively. The availability of *in-situ* measurements and multiple detection analyses has expanded the water monitoring applications in various advanced techniques including successful establishment in hand-held sensing devices which improves portability in real-time basis for the detection of contaminant, such as microorganisms, pesticides, heavy metal ions, inorganic and organic components. This paper intends to review the developments in water quality monitoring technologies for the detection of biological and chemical contaminants in accordance with instrumental limitations. Particularly, this review focuses on the most recently developed techniques for water contaminant detection applications. Several recommendations and prospective views on the developments in water quality assessments will also be included.

Contents

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List of Acronyms

AACC	American association of cereal chemist
AC	Alternating current
AI	Artificial intelligence
ANN	Artificial neural network
ATR	Attenuated total reflectance
BSA	Bovine serum albumin
CE	Capillary electrophoresis
CCD	Charge coupled device
CDOM	Chromophoric dissolved organic matter
DIS	Dielectric impedance spectroscopy
DMF	Digital microfluidic
DNA	Deoxyribonucleic acid
DOM	Dissolved organic matter
DTM	Dynamic threshold method
EC	Electrical conductivity
EIS	Electrical impedance spectroscopy
EPA	Environmental protection agency
EWOD	Electrowetting-on-dielectric
EWS	Early warning system
FDOM	Fluorescence dissolved organic matter
FIR	Far infrared
FISH	Fluorescence in situ hybridization
FPGA	Field-programmable gate array
FTIR	Fourier transform infrared spectroscopy
GCMS	Gas chromatography mass spectrometry
HCA	Hierarchical cluster analysis
HPLC	High performance liquid chromatography
ICPMS	Inductively coupled plasma mass spectrometry
IR	Infrared
LAMP	Loop-mediated isothermal amplification
LCMS	Liquid chromatography-mass spectrometry
LCOF	Liquid core optical fibre
LCW	Liquid core waveguide
LED	Light emitting diode
LOADEST	Load estimator
LOC	Lab-on-a-chip
LPFG	Long-period fibre grating
MIR	Mid infrared
MVE	Minimum volume ellipsoid
MPN	Most probable number
MS	Mass spectrometry
NIR	near infrared
ORP	Oxidation reduction potential
PBS	Phosphate buffered saline
PCA	Principal component analysis
PCR	Polymerase chain reaction
PFC	Perfluorinated compounds
POC	Point-of-care
PSA	Prostate specific antigen
SARS	Severe acute respiratory syndrome
SERS	Surface enhanced raman spectroscopy
SPA	Sensor placement approach
SPE	Solid phase extraction
SVM	Support vector machine
TDLAS	Tunable diode laser absorption spectroscopy
TN	Total nitrogen
TNT	2,4,6-trinitrotoluene
TOC	Total organic carbon
TU	Turbidity
UN	United nations
UNESCO	United nations of environment, scientific and cultural organization
UNICEF	United nation children's fund
USEPA	United state environmental protection agency
UV	Ultraviolet
VDA	Vector distance algorithm
WDS	Water distribution system
WHO	World health organization
μPADs	Microfluidic paper-based analytical device
μTAS	Micro total analysis system

1. Introduction

Waste production from agriculture, industrial sewage, animal and human activities are affecting the boundaries between clean water and wastewater, causing the reduction in the fresh water supply for human. Water ecology provides services such as food production, nutrient cycling, habitat provision, flood regulation, water purification and soil formation [1]. Biological and chemical contaminants in tap and drinking water, initiate the evolution of contagious diseases [2]. Therefore, fast and sensitive detection techniques are crucial to ensure safe and clean water supply. Unsafe water supply affects human health, causing contagious diseases such as hepatitis, influenza, SARS, pneumonia, gastric ulcers and pulmonary disease [3]. There are numerous non-biological contaminants existed in the water supply and some of the examples are silica, sodium, sulphur, ammonia and chlorine [4]. Other hazardous substance of heavy metals such as cadmium (Cd), lead (Pb), arsenic (As), mercury (Hg) and nickel (Ni) are also found in water supply [5]. These non-biological contaminants are among the commonly detected pollutants in urban areas that constitute a wide array of human activities.

The preservation of water quality has been regulated since the introduction of directive *91/271/EEC*, which requires accurate treatment process targeting on organic contaminants, nitrogen and phosphorus [6]. In addition to these contaminants, other concern on the water quality includes the existence of microbiological contaminants in tap and drinking water at point of consumption. Derivation of pathogenic activity in water supply poses serious threats not only to human but also the entire water ecosystem. Pathogenic microorganisms can be categorised into bacteria (e.g., *Salmonella typhi*, *Vibrio cholera* and *Shigella*), viruses (e.g., *Poliovirus*) and protozoa (e.g., *Giardia lambia* and *Cryptosporidium*). These types of microorganisms have been periodically detected in the water

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