Detection of Arsenic in Water-A Review on Different Methods

Namrata Bhalerao
Vidyalankar Institute of Technology
University of Mumbai
Wadala, Mumbai 400037, India
namratabhalerao22@gmail.com

Sheetal Mapare
Vidyalankar Institute of Technology
University of Mumbai
Wadala, Mumbai 400037, India
Sheetal.mapare@vit.edu.in

Vaibhav Kshirsagar
Vidyalankar Institute of Technology
University of Mumbai
Wadala, Mumbai 400037, India
Vaibhav.kshirsagar@vit.edu.in

Abstract – Arsenic is one of the chemical element that can poison the groundwater and can lead to many human health effects. As it is difficult to detect the arsenic in water it can affect many people's life, as long-term exposure to arsenic can cause many cancerous and non-cancerous diseases. Consuming large amount of arsenic causes arsenic poisoning or aesenicosis. Arsenic is present in groundwater all over the world. It is a semi-metallic compound. Health risks caused by arsenic if not treated may lead to death, so precautions must be taken for those who are at risk. Arsenic can enter into human bodies through contaminated groundwater, arsenic preserved wood and infected soil and rock. Arsenic is found in two forms namely organic and inorganic. Inorganic arsenic is classified into two types namely As(III) and As(V). In this paper, we are discussing about the various techniques which are being used for detection of arsenic.

Keywords – Inorganic arsenic, Environmental Protection Agency, Groundwater, Anodic stripping voltammetry, Biosensors. Groundwater. Arsenic. Assay. BioBricks.

I. INTRODUCTION

Arsenic contaminated in water is a serious issue to human health. The World Health Organization (WHO) and the United States Environmental Protection Agency (EPA) both define the Maximum Contaminant Level (MCL) of arsenic in drinking water at 10 parts per billion (ppb), yet the arsenic concentration levels in many locations worldwide exceed 50 ppb. Water contaminated with arsenic is colorless, odorless, and tasteless, and until it is consumed for long time it may not have any adverse effects. As a result, there are approximately 100 million people globally at risk due to long-term consumption of water containing arsenic. Long-term exposure to arsenic has been associated with cancer of urinary tract, liver, kidney; also some skin related infections and other effects can include reproductive and child development health repercussions which are non-cancerous. For these reasons, various kinds of testing is carried on in critical areas which may lead to arsenic poisoning[1].

Current solutions for arsenic detection are simple colorimetric techniques and also some laboratory tests. Colorimetric kits are simple and low-cost, but these kinds of tests generally do not have proper precision, have a higher limit of detection (>10 µg/L), and use toxic chemicals as test reagents [6]. Laboratory-based techniques, such as inductively coupled plasma mass spectrometry (ICP-MS), atomic fluorescence spectroscopy (AFS), and HPLC-MS, are accurate but are more expensive, that requires analysis of offsite sample, causing wide adoption of such techniques in the affected countries. The current technologies for on-site field detection have to be done properly, and there is significant scope for improvement. There are lot of countries affected by arsenic approximately 20 countries, out of which four major are from Asia. These include Bangladesh, India, Inner Mongolia and Taiwan. Fifty districts of Bangladesh and nine in West Bengal (India). And these countries have arsenic levels in drinking water above the World Health Organization's arsenic guideline [6].

The most popular solution now a days is to use the Arsenic Detection Kit. But for the field work it is complex as it contains many chemical reagents and also it depends on the visualization of the user [10]. Several techniques have been found for detecting inorganic arsenic in water. These techniques will be studied in this review [3].

II. ELECTROCHEMICAL ANALYSIS OF ARSENIC

To detect arsenic, electrochemical detection method is used in which microfluidic sensor is used. There are three electrodes in the sensor which is printed by inkjet conductive ink electrodes. Using cyclic voltammetry, detection of arsenic via electrochemical technique is carried out.

In cyclic voltammetry, a silver working electrode, and a silver/silver-chloride reference electrode is used as a sensor for the detection of arsenic along with two different electrochemical analyzers. The sensor is dipped in water to check the concentration of arsenic. If the arsenic is not present the current value in working electrode is to be neglected. In the presence of arsenic concentration of about 1ppb, a robust increase in current value is observed which shows that higher the arsenic concentration in the water, higher will be the current values produced by the sensor.

The electrochemical methods consists of :

1.Polarography: To determine the trace of inorganic metals polarography technique is used which is being implemented from past many years. It is a voltammetric measurement

which is based on the principle of studying the sample using electrolysis and two electrodes, one is polarizable and the other is non-polarizable. Mercury is dropped on the polarizable electrode via a capillary tube. Since mercury falls on one electrode, the surface area changes. This causes capacitive current to flow through the system, thereby limiting the detection range.

2.Cathodic Stripping Voltammetry (CSV): Cathodic Stripping voltammetry is a voltammetric determination method for detecting arsenic. It is done by using copper or selenium to react with arsenic in order to form favorable compounds at anode, that form arsenic hydride at the cathode. This increases the sensitivity of the system. It is based on the reduction of As(V) to arsenic hydride. Electrochemical method has sequential output, power requirement is low and good output quality, it is Less expensive than most other arsenic detection techniques also Can be used in remote places and very small in size. But shelf life is Short or limited. An electrochemical sensor usually has a shelf life of six months to one year, depending on the target material and the environmental condition where detection is performed.

III. Anodic Stripping Voltammetry

The arsenite As (III)is detected by using Anode Stripping Voltammetry. Here also they are using three electrode system . The first electrode is counter electrode then second is the working electrode and third is the reference electrode. Earlier this electrode system was printed on the various substrate. Here the working electrode is coated with the ionophore . This sensor is highly sensitive micro sensor. TMOPP-Co (tetrakis methoxyphenyl porphyrinatcobalt (II) was chosen as ionophore due to its superior performance in ion selective electrodes. A mixture of PVC(poly vinyl chloride) and DBBP(dibutyl butyl phosphate) was utilized as the plasticizer to ensure the physical properties of the film and the mobility of the constitute. The sensor's low detection is obtained due to perm selectivity of ionophore film, compared with traditional ASV.

This film act as blocking layer for ions and prevent them from diffusing into the working electrode surface and hindered the electron transfer. Combination of highly selective ionophore film and traditional ASV method, the background current of the stripping voltammetry is been reduced , leading to a higher signal to noise ratio. Here they have compared two results one with bare gold sensor and another with ionophore - coated sensor with a solution of 50ppb As(III). In a bare gold sensor, various ions are attracted on the working electrode around the senor while in ionophore-coated sensor the ions except As(III) are attracted. As we know due to this technique background current is reduced. Also another advantage is that it greatly improves the consistency and repeatability of the ASV sensor. In this also they have performed square wave anode stripping voltammetry and stripping voltammograms were obtained between 0 to 50ppb solution with As(III) . In this they achieved 1.09ppb limit of detection. This is a novel method to determine As(III) . This sensor is low cost and highly sensitive sensor.

IV. Detection Of Arsenic Using Color Sensor

Modern arsenic detection kit along with color sensor is used for detection of arsenic. Many techniques have been developed for detection of arsenic as in electrochemical electrodes, photo system and different types of chemical agents. These techniques are little complex and not suitable for the rural area's uneducated people. So research was done to obtain a simple method. Here, they have used an arsenic detection kit along with color sensor. Firstly, color intensity of different percentage of contamination that was seen using traditional arsenic detection kit was captured by RGB colour sensor and stored in microcontroller.

This was considered as ideal value. After that water samples from different areas were taken and tested using detection kit. Each water sample describes different color intensity on the stripes. Then the color intensity again was captured using same RGB color sensor and then intensity of it was compared with ideal value. Microcontroller automatically matches the color intensity. There were different color sensors in the market one of them is the RGB color sensor. It represents the color in 3-dimension space. They calibrated the sensor and calculated a table which showed the RGB values present in the sample. By using these they determined the percentage of arsenic in the solution. Due to chemical complexity and operator's visualization, the process of testing is tough for the rural people as well as normal people. But due to use of the color sensor technique all these issues were eliminated. It is safe and risk free.

V. Neutron Activation Analysis (NAA)

In Neutron Activation Analysis the sample undergoes some activation process. It forms radioactive nuclides which are decayed through emission of beta particles and gamma rays with unique half-life. A spectrometer is used to detect the gamma rays produced. The spectrometer used is of high resolution. This technique is sensitive amongst all so mostly it uses some references for implementing many new methods. There are high concentrations of salt in sea water which can cause many spectral interferences. And NAA has not yet found some wider methods that could detect the arsenic content in water. Adding Pb(NO)3 and TiCl3 as carrier and reducing agent the problem may get fixed.

VI. Colorimetric Technique

The detection of metal ions can be done in aqueous solution by using nanoparticles medication in suitable waveguides turns out to be a effective option. NPs are basically different from its bulk materials due to their shape, size, interparticle distance, and surrounding dielectric environment. The unique physical, chemical, and electronic properties of NPs have paved ways for intense application in sensing yields. It is worth mentioning that extensive research has been reported to detect heavy metal ions based on colorimetric approach due to inherent implicitly and cost effectiveness. The most important factor is that the solution

can been seen by the naked eye. AuNPs are used as sensing units. AuNP is prepared by Heating 100 ml of 1mM gold chloride solution in a conical flux on a stirrer. When solution appears red-wine color it is kept in room temperature.

Mangifera indica leaf extract (MILE). is used to to detect arsenic in a eco friendly approach. In order to clean the Mangifera indica leaf, it is cleaned in running water, after which it is cleaned in double distilled water multiple times and it is dried for 30 mins at room temperature. From these dried leafs, 10 g is taken and cut into small pieces. In 100 ml distilled water, these leaf pieces are boiled for 15 min at 60 °C. The solution gets filtered through Whiteman filter paper after the cooling of the solution. After filtering the MILE solution turns into light yellowish in color.

Leaf extract modified AuNPs are taken in centrifuge tubes for the detection of metal ions. To these tubes, different solutions of ions, such as copper, arsenic, lead, mercury, nickel, cobalt, magnesium, and cadmium, are added. An excellent change in arsenic containing tube was observed by the leaf extracted modified AuNPs. Due to localized surface eplasmon resonance (LSPR), NPs have shown different colors. This LSPR property of NPs depends on shape, size, and interparticle distance. MILE has several biomolecules, such as flavonoids, terpenoids, and thiamine These biomolecules include the amino group(–NH2) and the hydroxyl group (–OH). amino and hydroxyl groups. As the functionalized NPs interact with arsenic ions, they facilitate binding of this metal ion with the amino and hydroxyl groups. Consequently, interparticle distance among the NPs is reduced, leading to aggregation of NPs. This aggregation process alters the color of AuNPs from reddish wine to violet in the tube that contains arsenic. With higher concentration of arsenic, a saturation stage is reached as the aggregation of NPs eventually ceases.

Nanoparticle technique is cheaper than electrochemical but uses toxic chemical as reagents and the limit of detection is greater than other arsenic detection techniques.

VII. BIOSENSING TECHNIQUE

Bio-sensing technique is an alternative method for detection of arsenic in water. The Registry of Standard Biological Parts derived the Bio Brick assay construct, pSB1A2- BBa_J33203. The conduction of assay with 6 ml lactose plus LB and other substances to improve the conduction in 20 ml sealed glass vials, kept warm with shaking at 37 C, using 1032 K. de mora et al. (a standard semi-micro glass pH electrode) the PH was measured at different intervals. The desired mixture of sodium arsenate and 1 ml AMB6 added to tube of dried cells in the later assays. For simultaneous visual monitoring of multiple assays, up to 50 tubes were placed in a specially constructed rack in a 37 °C incubator with a clear front cover. Conducting Miller assays of β-galactosidase XylE activity (catechol-2,3-dioxygenase) was monitored by adding catechol to a final concentration of 0.1 mM to cell suspension and monitoring absorbance of the yellow reaction product (2- hydroxy-cis, cis-muconic semialdehyde) at 420 nm. To clarify the different growth parameters effect, firstly, investigation of the effect of using a more dilute growth medium was done. Use of LB diluted by a factor of 2 or 4 showed the higher dilution factor medium led to less pH decrease in arsenic-free controls while maintaining a strong pH response to 60 ppb arsenic, but further dilution led to a decreased pH response in the presence of arsenic. Investigation of different levels of inoculum was also done. A larger inoculum led to more rapid response, but where samples were incubated for longer periods, tiny difference was observed to the final pH over the range tested due to the level of initial inoculum.

For field use, this assay configuration is not the practical method. Phosphate at relevant levels was found to have no effect on the assay but bicarbonate was unexpectedly found to apparently increase the sensitivity of the assay, leading to enhanced pH response at low arsenic conditions. The newer version of the biosensors is constructed to define the basis of this effect by the addition of second reporter gene, xylE (encoding catechol-2,3- dioxygenase; Bio Brick BBa_J33204) to the Bio Brick biosensor plasmid, giving the new biosensor construct pSB1A2-BBa_J15501. In the presence differing levels of bicarbonate and arsenate, Biosensors organisms are incubated and assayed for pH, β-galactosidase activity (Miller assay) and XylE activity. As previously observed, the pH assay showed an enhanced response to low arsenate concentrations in the presence of bicarbonate, whereas no difference was seen at higher arsenate concentrations, thus, the presence of bicarbonate appeared to increase the sensitivity of the assay. However, In Miller assays, it is shown that in the presence of low and high arsenic concentrations, β-galactosidase activity is increased. thus, it appears that the apparent lack of effect of bicarbonate on the pH-based assay at high arsenate concentrations is an artefact caused by saturation of the pH response above a certain β-galactosidase activity. Furthermore, in the presence of arsenate XylE activity was also seen increased despite of high background activity, suggesting that the effect was due to increased induction of the reporter genes rather than some direct effect on the activity of β-galactosidase. It therefore seems likely that bicarbonate is increasing the interaction of arsenate with the ArsR repressor protein, perhaps by increasing entry of arsenate into the cell or modifying arsenate speciation.

Advancement in biology has allowed scientists to configure enzymes. Enzymes for detection of arsenic have been developed. Enzymatic Catalysis is a technique which utilizes the properties of enzymes for detection of trace amounts of a material. In this case, arsenic in water. The technique employed an enzyme that produced fluorescent compounds as per the concentration of arsenate compounds in water. The light emitted by this fluorescent compound can be measured to determine the arsenic concentration. This method can detect less than 10ppb of arsenic concentration which is below the allowable limit adopted by World Health Organization (WHO) which is 10ppb allowed in drinking water. The technique achieved a detection range of 0-200 ppb.

VIII. CONCLUSION

In this review most popular techniques for detection of arsenic have been determined. As we saw there were excess amount of techniques for arsenic detection in water. Also combination of techniques has been done according to the needs. The electrochemical technique is a good but its shelf life is short. Detection using colour sensor is easy technique that can be used by rural people but accurate results is difficult to obtain. Nano particle technique is better that electrochemical but uses chemical reagents. Thus, there is a need for a rapid and accurate sensor. Lot of advancement have developed biosensing technologies. These techniques are novel and can have great scope for improvement. All these techniques try to achieve low limit of detection as per the WHO guidelines.

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