Paptode: An Analytical Tool Proceeding towards Green Chemistry

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ABSTRACT
Green chemistry is carrying out chemical activities, including chemical design, manufacture, use, and disposal, such that hazardous substances will not be used and generated. It is a tool in accomplishing Pollution Prevention. It encompasses all aspects and types of chemical processes to reduce impacts of hazardous substances. Green chemistry is the use of chemistry for pollution prevention, design of chemical products and processes that are more environmentally benign and reduction or elimination of the use or generation of hazardous substances associated with a particular synthesis or process. Green chemistry shifts financial resources from costs to research & development. It promises to lower overall energy consumption and costs associated with environmental health and safety. Paptode developed for detection and removal of heavy metals also work on the principles of green chemistry. It is highly cheap and user friendly device. It is prepared simply by dipping green substrate such as paper, clay, TLC (thin layer chromatographic) paper, cotton or any absorbing material into suitable reagent system. A colored reaction product can be produced on the surface of reagent impregnated inert support, by a single drop of solution of analyte, producing distinct flecks or rings. This local accumulation accompanying spot reaction enhances discernibility of colored reaction products. The degree of color of the spot was found to be proportional. The proportionality in intensity of the spot color on the paptode loaded with varying amounts of analyte suggests its potential applications for environmental monitoring and hence waste management. The paptode can also be used for pollutant check at home. Thus the paper optode has great potential for this purpose and is progressing towards green chemistry.

Index Terms—Paptode, green chemistry, hazardous substances and green substrate.

I INTRODUCTION

Environment is a heritage for all. Each of us has a role to play in a rehabilitating our environment. . It should be the duty of every citizen to protect and improve the natural environment. It is thus constitutional obligation of the state and of every citizen of the country to preserve and protect the natural environment [1]. Pollution is the introduction of contaminants into a natural environment that causes instability, disorder, harm or discomfort to the ecosystem i.e. physical systems or living organisms. There are a number of chemicals present in the environment. They get into human food chain from the environment. Once they enter our biological system they disturb the biochemical process, leading in some cases to fatal results [2]. To protect our environment and human race from these fatal chemicals and prevent this pollution it is necessary to search some new materials and process which are alternatively used without harming the environment. For this environmental movement, alternative synthetic pathways for Pollution Prevention are used such as, design synthesis of chemicals for PP and collaborations, voluntary partnerships. Approaches which are utilized in recent past include reduction of risk of manufacturing, use of innovative chemistries to treat wastes and remediate sites, new monitoring and **analytical tools** for detection in air, water, soils and new handling and containment procedures to minimize exposure.

Green chemistry acts as a **tool** in accomplishing Pollution Prevention. Green chemistry is the use of chemistry for pollution prevention, design of chemical products and processes that are more environmentally benign, reduction or elimination of the use or generation of hazardous substances associated with a particular synthesis or process.

It encompasses all aspects and types of chemical processes to reduce impacts of pollution on environment. Green chemistry carries out chemical activities, including chemical design, manufacture, use, and disposal, such that hazardous substances will not be used and generated [1].

II PAPTODES

The paptodes are also an optical chemo sensor where reagents are immobilized on an adsorbent material which could be clay, simple filter paper, chalk powder, Whatman filter paper or even thin layer chromatographic paper and are advantageous over optodes [3].

(a) Advantages over optodes

(i) The immobilization of reagent is very easy in case of paptode

(ii) In this method, we can introduce several reagents on a single strip. Therefore, by using a series of non-specific (or even low-selective) reagents, we can estimate the quantity and quality of multiple analyte in the solution by applying of mathematical methods, exactly similar to the analysis of **tongue's signals in our brain**.

(iii) Since diffusion in a porous material is higher than in polymeric membrane the **response**

time in paptodes is shorter than typical optodes.

(iv) The uniformity pattern is not important in paptodes.

(v) These are portable.

Paper, which is relatively cheap, abundant, sustainable, disposable and easy to use, store, transport, and modify, has recently re-emerged as an attractive substrate material for sensing. The sensors on paper are considered as user-friendly alternative to conventional analytical instrumentations for 'point of-care' medical diagnosis, environmental monitoring, and food quality control. In fact, paper-based analysis has been widely used in our daily lives such as pH test paper [4].

III CONSTRUCTION OF PAPTODE

Construction of paptode is a very simple process. Before preparation of paptode for a particular metal ion, the new reagent system is developed to check its sensitivity and linearity to determine the toxic heavy metal ion. Then disposable paptode is prepared by immobilizing the same reagent on any reagent support substrate such as Whatman filter paper, clay, sand, chalk powder, TLC paper and even ordinary filter paper followed by drying in oven. In present study; immobilization of reagents is carried out on TLC paper.

IV STORAGE OF PAPTODE

The developed paptodes were stored in dry glass or plastic boxes preferably in dark to avoid environmental exposure. The storage period differs for different reagent system.

V DUAL NATURE OF PAPTODE

The developed paptodes serve as sensor as well as filter. When the interest is to detect heavy metal present in the sample below TLV it acts as sensor and detects much lower than standard TLV. When we know the concentration of particular toxic metal ion in aqueous sample and would like to bring down its concentration below TLV and thus to make the sample safe for use; the paptode can be used as filter and serves the purpose by batch removal till the concentration in aqueous sample reaches as desired. Nevertheless of our best knowledge; such dual nature paptodes have been developed.

VI METHODOLOGY

A new optical analytical method, "digital RGB Analysis" based on MATLAB image processing tool is utilized to use paptode as an analytical tool. MATLAB image processing tool can transform the color information into digital RGB values, color library data that can be treated as analytical information. Image processing tool can simulate the optimum color variations by optimization of visual color sensor with computer assistance. By utilizing color as digital information, colorimetric analysis can serve as an accurate quantitative determination method instead of semi quantitative analysis.

Colored spots were scanned using a commercially available flatbed scanner and the obtained images have been transferred to a computer for **RGB analysis** through **MATLAB** and the intensity of the color-spots was determined. The RGB color model is an additive color model in which red, green and blue light are added in various ways to produce a broad array of colors. Any color can be analyzed to obtain its corresponding R, G and B value. The effective intensity for any color values of color spots was calculated as follows:

$A_r = -\log(R_s/R_b)$ ---------- (1); $A_g = -\log(G_s/G_b)$ ---------- (2); $A_b = -\log(B_s/B_b)$ ---------- (3)

where A_r, A_g, A_b are effective intensities of the red, green and blue color respectively, R_s, G_s, B_s and R_b, G_b, B_b refer to R, G and B values of the sample and blank respectively.

VII RESULT AND DISCUSSION

We have developed paptodes for As, Se, Hg, Pb, Zn, Cd and Cu [5-11]. Out of which As, Hg, Pb and Cd are considered highly toxic

Parameters like injection volume, reagent concentration, effect of temperature, drying methods, response time, reproducibility, effect of interfering species and application of paptode for detection and removal have been tested. The paptodes for different entities have been found successful to detect the species below the TLV (threshold limit value or toxic limit value) and to remove effectively [5-11]. Table I summarizes the parameters and removal percentage of various paptodes developed by us. Photograph 1 shows the developed paptodes.

Table 1
Detailed Parameter of Developed Paptode

Parameter	Toxic Element						
	As	Hg	Se	Zn	Cd	Pb	Cu
Injection Volume	18 µl	18 µl	24 µl	6 µl	18 µl	24 µl	12 µl
Drying Method	RT	RT	RT	RT	RT	RT	RT
Temperature Dependence	No Effect	No Effect	Gentle heat	No Effect	60-70°C	No Effect	70-80°C
Range of Determination	0.18-1.8 µg mL^{-1}	0.18-18 µg mL^{-1}	0.24-240 µg mL^{-1}	0.8-6.0 µg mL^{-1}	µg mL^{-1}	0.024-11 µg mL^{-1}	0.012-8.4 µg mL^{-1}
Limit of Detection	18 ng	6 ng	120 ng	15 ng	3 ng	3 ng	15 ng
Stability of Paptode	10 days	20 days	10 days	15 days	20 days	15 days	40 days
Stability of spot	24 hours	3 days	2 days	3 hours	2 days	2 days	2 days
Response Time	25-30 min	Instant	Depends on Conc.	Instant	15 min	Instant	15 min
% Removal	95%	90%	90%	98%	95.5 %	95%	90%

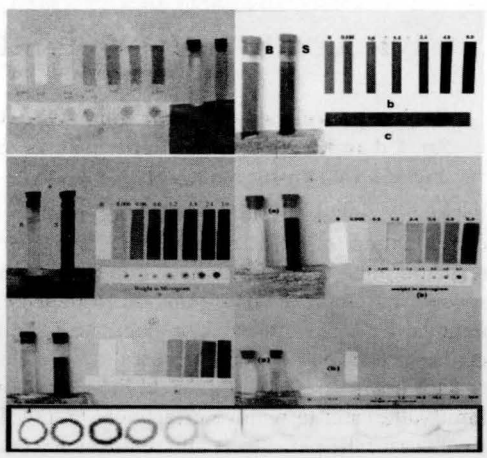

Fig 1 Photograph showing developed Paptodes

VIII CONCLUSION

The paptodes developed have utilized very little reagents, use paper as a cheaper substrate. These not only detect the presence of toxic entity and determine but also effectively remove heavy metal ions without using any costly instrument. The dyes so formed on paptode by complexation can be further recovered. These are user friendly and are potential device to be commercialized for routine health and pollution analysis. Looking to these benefits and dimensions of use, the developed paptodes are certainly an analytical tool proceeding towards green chemistry.

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