# *PAPER-BASED ANALYTICAL DEVICE* FOR DETECTION OF METAL, NON-METAL, AND ORGANIC POLLUTANTS: REVIEW

**Rieda Nurwulan S, Aliya Nur Hasanah**
Faculty of Pharmacy University of Padjadjaran, Indonesia
*E-mail*: riedans97@gmail.com

## Abstract

*The environment is the unity of space with all things, energy, circumstances, and living things, including human and his behavior, which affects nature itself, continuity of life, and human welfare and other living beings. Today, the environment has been polluted by the impact of intentional and unintentional human activities. To detect that an environment is contaminated the method it still expensive and difficult, that's why the method to analysis environmental pollution is still rarely done. Paper-based Analytical Device is an analytical method that is now often used to detect many things, from chemical compounds, bacteria, pollutants, and use for diagnostics. In this method, only samples with small volumes are required. Nor does it need external support equipment because the sample fluids are controlled largely by capillarity and evaporation. Many researchers now use PAD as an alternative method to test the contaminants present in an environment such as metal contaminants, non-metals, and organic compounds.*

***Keywords:*** *Environmental pollution, Paper-based Analytical Device, metal, non-metal, organic compound.*

Diserahkan: 30 Agustus 2018, Diterima 1 September 2018

## INTRODUCTION

The environment is where people live and carry out all forms of activity. Constitution No. 32 of 2009 on Environmental Protection and Management defines the environment as a unity of space with all objects, power, circumstances, and living things, including human beings and their behavior, affecting nature itself, the survival of life, and human well-being and other living beings (Undang-Undang Nomor 32 Tahun 2009, 2009).

Today, the environment is already damaged, because there is a lot of pollution and pollution in various environments either land, air, or air. According to Constitution No. 23 of 1997, the meaning of environmental pollution is the entry or inclusion of living creatures, substances, energy, and/or other components into the environment by human activities so that the quality is down to a certain level that causes the environment cannot function in accordance with designation (Undang-Undang Nomor 23 Tahun 1997, 2007).

In 2016 the Indonesian Central Bureau of Statistics released a book about "Statistik Lingkungan Hidup Indonesia" in which there are data of environmental pollution from all provinces of Indonesia are grouped into the water, soil, and air pollution. Data were taken in 2011 and 2014. From the data, it is known that in 2011 water pollution is the most complained pollution, while in 2014 the most contaminated pollution is air pollution, because of the increasing number of existing motor vehicles (BPS, 2016).

Most methods used to analyze environmental pollution are difficult methods and require a long time in the process, other than that the tool used its price quite expensive. Therefore, environmental pollution analysis is not done very often.

Microfluid Paper-Based Analytical Devices (μPADs) is a method or device developed firstly by Martinez et al, in 2007 which has now become a promising method for developing countries because of its ease of use, cheap maintenance and is specially designed for use in the developing country. In this method, only samples with small volumes are required. Also it does not need external support equipment because the sample fluids are controlled largely by capillarity and evaporation (Martinez A. W., 2010). The manufacturing process of μPADs is based on pattern making on a hydrophilic sheet (paper) constrained by a hydrophobic polymer (Martinez A. W., 2007). μPADs can detect various analytes including proteins (Martinez A. W., 2008), pathogens (Yetisen, 2013), chemicals, heavy metals (Apilux, 2010) , and drugs (White, 2013).

## DISCUSSION

Paper-Based Analytical Device has been widely used in various fields, one of them use in the field of environment to detect environmental pollution in the form of metal, non-metal, and organic compounds.

### a. Metal

Metal is one of the pollutants that is dangerous because it can cause poisoning when absorbed excessively. [11] Metals are called as pollutants because some metals are heavy metals that are very difficult to decompose with biodegradation. In addition, heavy metals can also accumulate in the environment especially in river and sea sediments as they can be bound to organic and inorganic compounds by adsorption to form complexes (Susiati, 2009).

Some metals that have been analyzed with PAD is Fe, Cu, Ni (M. M. Mentele, 2012), Cr, Pb, Cd (P. Rattanarat, 2013), and Zn (Kudo, Yamada, Watanabe, Suzuki, & Citterio, 2017).

The study using μPAD to analyze Fe, Cu, and Ni metals was performed by Mentele, et al in 2012. Using a sample of ash the resultant incinerator is converted to gas (aerosolization) and collected in a filter before it will be analyzed using μPAD. At this time obtained the detection limit of this method is 1.0-1.5 μg (M. M. Mentele, 2012).

For Cr analysis using μPAD the sample used is also the gas sample of the incinerator. The Cr present in the sample prior to it must first be changed to Cr (IV). In μPAD, there is 1,5-diphenylcarbazide which will react with Cr (IV) to form 1,5-diphenylcarbazone (DPCO) and Cr (III), where the two results of this reaction will form a purple complex. The resulting color intensity will be analyzed with desktop scanner software. The detection limit of this analysis is 0.12 μg (P. Rattanarat, 2013).

The μPAD used for the analysis of Pb and Cd is slightly different from the μPAD used for the preceding metal analysis since in this analysis the μPAD used is a plated μPAD. This layered μPAD consists of two layers wherein the first layer is used for colorimetric testing, while the next layer is performed for electrochemical testing. In the test there are 6 metals analyzed Cu, Ni, Fe, Cr, Pb, and Cd, where Cu, Ni, Fe, Cr are used for colorimetric testing, while Pb and Cd for electrochemical testing (P. Rattanarat, 2013).

For Zn analysis, samples used are samples derived from water taken from taps and rivers. In this analysis, we will examine the presence of Zn ions in the sample using the principle of colorimetric. Zn will react with the Zincon indicator to produce a pink color. Zincon is a water-soluble indicator, causing at the time the sample is inserted Zn2+ fails to form a complex with an indicator because the indicator is carried by water. Therefore it needs a compound to hold the Zincon indicator so it can react with Zn2+. The compound used is a water-soluble cationic polymer (PDDA). This PDDA (1%) is

added to the detection paper using an inkjet printer, which is carried out for 10 cycles (Kudo, Yamada, Watanabe, Suzuki, & Citterio, 2017).

**b. Non-Metal**

The excess of non-metallic compounds in an environment is not good. For example, when the levels of nitrates and phosphates at sea are excessive, there will be eutrophication (enrichment of nutrients) characterized by the occurrence of phytoplankton blooming which causes the death of various marine species (Simanjuntak, 2012).

The development of methods for measuring non-metallic elements has been widely practiced, one of them with μPAD. Some of the non-metallic compounds that have been analyzed with μPAD include phosphate (B. M. Jayawardane I. D., 2012), nitrates, nitrite (B. M. Jayawardane S. W., 2014), and ammonia (Y. Chen, 2014).

Phosphate analysis using μPAD is based on the principle of colorimetry in which the phosphate reacts with the molybdate compound to form a blue-colored complex in an acidic condition. In the μPAD analysis, the method is used uniquely, where the paper used is folded into 2 parts where in Zone 1 (part 1) will be given ascorbic acid reagent (acid regulator) and in Zone 2 (part 2) will be placed molybdate reagent. If it has not been already used the two zones must be coated or separated with cellulose acetate sheet. Both zones should be done because, in the form of mixtures, the reagents can only last for less than 24 hours. When the cellulose acetate sheet is removed the sample is dropped in zone 1. The resulting color intensity is measured using a flatbed scanner. (B. M. Jayawardane I. D., 2012)

Jayawardane et al, published the nitrate and nitrite analysis using μPAD. Nitrite is analyzed by Griess's reaction which will produce a red-violet color. While the nitrate will be reduced first by using the immobilized Zn. So there are two hydrophilic channels in one μPAD paper, where channel 1 is used as a nitrate reaction site to nitrate while channel 2 is a nitrite reaction site with griess reagent (B. M. Jayawardane S. W., 2014).

In addition to nitrate and nitrite testing Jayawardane et al, also performed ammonia testing using μPAD. In the test conducted by Jayawardane et al, used two layers of paper where the two papers will later be stacked and called zone 1 and zone 2. Almost the same as the method used for phosphate analysis. Only in this method zone 1 and 2 zone separating layers are Teflon (PTFE) which at the time of the analysis does not need to be released but can be used for diffuse samples. Zone 1 contains NaOH while Zone 2 contains the indicator reagent in this test. Two different ammonia indicator used are bromothymol blue and 3-nitrophenol. Both reagents are selected because they have a pH range close to pH 7. (Y. Chen, 2014)

**c. Organic Compounds**

If the organic compound has polluted the environment, the compound can survive for several decades and when exposed to humans can cause health problems such as cancer, the occurrence of defects in newborns, learning disabilities, immunological decline, behavior, neurological, and reproductive disorders in humans and other animal species. (A. Sweetman, 2005)

Phenolic compounds and their derivatives, is one of the by-products of the industry. This byproduct if not treated further will accumulate in the environment. The accumulation of these compounds in the environment can pose a toxic risk to human health and the environment. (R. S. Alkasir, 2012)

Analysis of phenolic compounds and their derivatives of phenol, bisphenol A, catechol and cresol have been performed by Ramiz et al. The analysis is based on the color change of chitosan after interaction with enzymatically produced quinones. The selective bond of the

reactive quinone derivative of phenol with the nucleophilic amino of chitosan will result in a reddish-brown coloration for phenol, turquoise blue for BPA, orange for catechol, m- and p-cresols. The colorimetric response depends on the concentration, with a detection limit of 0.86 (± 0.1) μg / L. (R. S. Alkasir, 2012)

In addition to phenolic compounds, it has also found volatile organic compound analysis using paper-based analytical devices. This analysis was carried out using paper dripped with diacetylene monomers (DA). Diacetylene monomer that used in this analysis there are 8 kinds of amphiphilic (1-6) and ballamphiphilic (7-8). Each Diacetylene monomer is dropped onto different paper. In this research we will test 18 volatile organic compounds of pentane, hexane, cyclohexane, toluene, o-xylene, benzene, diethyl ether, dichloromethane (DCM), chloroform (CHCl3), ethanol (EtOH ), ethyl acetate (EtOAc), acetone, methanol (MeOH), acetonitrile (MeCN), dimethylformamide (DMF) and dimethylsulfoxide (DMSO). 8 different diacetylene monomers were able to distinguish 18 VOCs in the vapor phase when used in combination with principal component analysis. In its optimum form, the array of 3 selected PDAs (2, 3, 8) is able to classify 18 VOCs with high reproducibility and discriminative capabilities. (T. Eaidkong, 2012)

## CONCLUSION

Paper-based analytical devices can be used as an alternative method to detect environmental pollution, including metal pollutants, non-metals, and organic compounds.

## REFERENCE

A. Sweetman, M. V. (2005). The Role Of Soil Organic Carbon In The Global Cycling Of Persistent Organic Pollutants (POPs): Interpreting And Modelling Field Data. *Chemosphere*, 959-972.

Apilux, A. D. (2010). Lab-on-Paper with Dual Electrochemical/Colorimetric Detection for Simultaneous Determination of Gold and Iron. *Analytical Chemistry*, 1727-1732.

B. M. Jayawardane, I. D. (2012). A Paper-Based Device For Measurement Of Reactive Phosphate In Water. *Talanta*, 454–460.

B. M. Jayawardane, S. W. (2014). Microfluidic Paper-Based Analytical Device (μPAD) For The Determination Of Nitrite And Nitrate. *Analytical Chemistry*, 7274–7279.

BPS. (2016). *Statistik Lingkungan Hidup Indonesia.* Jakarta: Badan Pusat Statistika.

Dungchai, W. C. (2009). Electrochemical Detection for Paper-Based Microfluidics. *Analytical Chemistry*, 5821–5826.

Ika, .. T. (2012). Analisis Logam Timbal (Pb) Dan Besi (Fe) Dalam Air Laut Di Wilayah Pesisir Pelabuhan Ferry Taipa Kecamatan Palu Utara. *Jurnal Akedemika Kimia* , 181-186.

Kudo, H., Yamada, K., Watanabe, D., Suzuki, K., & Citterio, D. (2017). Paper-Based Analytical Device for Zinc Ion Quantification in Water Samples with Power-Free. *Micromachines*, 127-139.

Li CZ, V. K. (2011). Paper based point-of-care testing disc for multiplex whole cell bacteria analysis. *Biosens. Bioelectron*, 4342–4348 .

M. M. Mentele, J. C. (2012). Microfluidic Paper-Based Analytical Device for Particulate Metals. *Analytical Chemistry*, 4474–4480.

Martinez, A. W. (2007). Patterned paper as a platform for inexpensive, low-volume, portable bioassays. *Angewandte Chemie International*, 1318-1320.

Martinez, A. W. (2008). Three-dimensional microfluidic devices fabricated in layered paper and tape. . *Proceeding of The National Academy of Science USA*, 19606-19611.

Martinez, A. W. (2010). Diagnostics for the Developing World: Microfluidic Paper-Based Analytical Devices. *Analytical Chemistry* , 3–10.

P. Rattanarat, W. D. (2013). A microfluidic paper-based analytical device for rapid quantification of particulate chromium. *Analytica Chimica Acta* , 50-55.

R. S. Alkasir, M. O. (2012). Colorimetric Paper Bioassay for the Detection of Phenolic Compounds. *Analytical Chemistry*, 9729–9737.

Simanjuntak, M. (2012). Kualitas Air Laut Ditinjau Dari Aspek Zat Hara,Oksigen Terlarut dan pH Diperairan Banggai, Sulawesi. *Jurnal Ilmu dan Teknologi Kelautan Tropis*, 290-303.

Susiati, H. A. (2009). Kandungan logam berat (Co,Cr, Cs, As, Sc, dan Fe) dalam sedimen di kawasan pesisir I semenanjung Muria. *Jurnal Pengembangan Energi Nuklir*. doi:http://dx.doi.org/10.17146/jpen.2009.11.1.1430

T. Eaidkong, R. M. (2012). Polydiacetylene Paper-Based Colorimetric Sensor Array For Vapor Phase Detection And Identification Of Volatile Organic Compounds. *Journal of Material Chemistry*, 5970–5977.

*Undang-Undang Nomor 23 Tahun 1997*. (2007, December 19). Diambil kembali dari Kementrian Lingkungan Hidup Republik Indonesia: http://jdih.menlh.go.id/

*Undang-Undang Nomor 32 Tahun 2009*. (2009, October 15). Diambil kembali dari Kementrian Lingkungan Hidup Republik Indonesia: http://jdih.menlh.go.id/pdf/ind/IND-PUU-1-2009-UU%20No.%2032%20Th%202009_Combine.pdf

White, W. W. (2013). Inkjet-printed paper-based SERS dipsticks and swabs for. *Analyst*, 965–1272.

Y. Chen, Y. Z. (2014). Paper Based Platform For Colorimetric Sensing Of dissolved NH3 and CO2. *Biosensors and Bioelectronics*, 477–484.

Yetisen, A. K. (2013). Paper-based microfluidic point-of-care diagnostic devices. *Lab on a Chip*, 2210-2251.