DEVELOPMENT OF LOW COST INTELLIGENT DEVICES FOR AIR AND WATER QUALITY MONITORING

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Abstract
There are different types of air and water quality monitoring instrumentation available, but they are very expensive for wide use in the developing countries. We have undertaken a project to develop intelligent & portable devices for air and water quality monitoring, which should have high selectivity properties, good detection limits, and should be attractive for use in the developing countries. A pilot study was conducted using monochromatic light from a light emitting diode, LED, (laser module TIM 20) with the wavelength 650 nm, and output beam effect 1mW. The light passed through a sample holder containing the sample in solution. Some of the incoming light was absorbed by the solution. The amount of light that penetrated the sample solution, transmittance, was detected by the photo diode, BPW34 to produce the output voltage. The output voltage varied linearly with the transmittance and that was found to be related to the concentration of the particles (contaminants). This device shows promising potentials for further development and can be attractive for wide use in the developing countries.

INTRODUCTION

In the megacities in the developing countries air quality has deteriorated and have severe effects on human health and mortality. Air pollutants increase the risk of infections of the respiratory tract, affect the cardiac and pulmonary system, lead to allergies, affect asthmatics and may also act as cancer precursors. Acute respiratory disease is responsible for some 4 million deaths a year of children under five in developing countries, second only to infant diarrhoea in its impact on mortality. Increased level of inhalable particles and carbon monoxide seriously effect people with respiratory diseases and also the people with cardiovascular disease (Miller 1997). A recent report by the World bank (2001) has estimated that 15000 death per year occur in Bangladesh, as a result of air pollution in the major cities. Several studies have shown the extremely high concentration of air pollutants in Dhaka city (Karim 1997). The table below shows the mean results of our measurements of some air pollutants from different places in Dhaka city in March 2001 (Mridha 2001).

Table 1: Air pollutants in Dhaka compared to WHO recommended standard:

Compound	Hourly extreme $\mu g/m^3$	Times the WHO recommended standard
NO_2	601-714	>10
SO_2	300-500	>10
Particles	5-400	>15
Ozone	600-900	>5
VOCs	783000	>50-100
Benzene	783000	>7-10
Toluene	200000□	>10

People in the rural areas of the developing countries are dependent on the supply of untreated water which is the root cause of their ailments as reports have confirmed that 90% of human ailments in rural areas may be accounted due to polluted water supply (WHO report 2001). The run off pesticides, fertilizers, heavy metals are the few well known sources of contamination of water. Between 30 and 36 million people in Bangladesh are estimated to be exposed to arsenic in drinking water at concentrations above 50 µg/l (WHO report 2001). Skin disorders including hyper/hypopigmentation changes and keratosis are the most common external manifestations, although skin cancer has also been indentified (Smedley and Kinniburgh) due to arsenic contamination in drinking water. Surprisingly little attention has been devoted to improving the health conditions of rural population in the developing countries although about 80 per cent of the population in the developing countries are concentrated in the rural areas. There is no prospect for community water supply in the rural areas of the developing countries and there is no system for professional control of water quality in the rural areas. It is therefore, urgent to develop appropriate water purification and water quality control technology for the developing countries so that the UN's goal **'Health for all'** can be met.

Unfortunately western technology including diagnostic health care technology available in the developing world do not function effectively for example because they are usually designed for uses in technically advanced countries (Mridha 1991,1992, 1993). They are often not well suited to applications in the developing countries due to the lack of well engineered basic elements or they are not simply affordable. The lack of attention paid by the technology designers and manufacturers to the local environment conditions, resources and capabilities of the developing countries is partly responsible for this situation (Mridha 1991, 1992, 1993). Other instruments and techniques which can differentially enumerate mixed suspensions are often very expensive and laborious, often precluding them from widespread routine use.

This paper suggests a technique applying smart sensor to determine pollutants in water and air. The instrument shows promising potentials to be cost effective, environmentally acceptable and more attractive for use in the developing countries.

METHODOLOGY

A pilot study was conducted using monochromatic light from a light emitting diode, LED, (laser module TIM 201) with the wavelength 650 nm, and output beam effect 1mW. The light passed through a cuvette containing sample solutions. Some of the incoming light was absorbed by the particles (pollutants) in the solutions. The amount of light that penetrated the sample solution, transmittance, was detected by the photo diode, BPW34, to produce the output voltage. The output voltage varied according to Beer´s lag as given by the equation below:

$$I_t = I_o e^{-\mu dc} \qquad \text{(equation 1)}$$

I_o is the intensity of the incident light, d is the thickness of the cuvette, c is the concentration of the particles and I_t is the intensity of the light detected by the detector on the opposite side of the light source, and μ is the absorption coefficient which varies with the substance and wavelength of the light. The block diagram below shows the test equipment for measuring absorbance at one single light wavelength. The major advantages in using laser light source is the fact that, the radiated effect is very stable and its monochromatic character provides desired specificity, sensitivity and signal to noise ratio. At the source wavelength of 650 nm, we got a sensitivity of 450 mA/W.

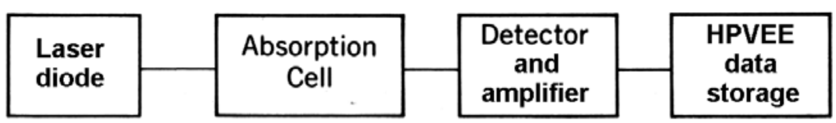

Figure 1: A simple bock diagram of the measurement system

The sample holders we used were ordinary laboratory cuvette with the size 12,5x12,5x44 mm. A simple test equipment was built with a measuring amplifier, a photo diode, a digital Multi-Meter, Fluke 45. The software, HPVEE was used to store and process the measurement data. To get information about the sensitivity and reproducibility of device, repeated measurements were made on different samples with varying concentrations. Mean values and standard deviations were calculated to study the statiscal significance of the results.

RESULTS

The results from the experiments showed that the absorption increased as the concentration of the particles were increased under controlled conditions. The results were reproducible and the differences between the different concentrations were statistically significant. All the simulated experiments showed similar results. The results from this pilot study suggest that a measurement method applying semiconductor light sources and detectors provide a suitable and real-time method for detecting contaminants in water. The method may be used for detecting contaminants in air and have potential for offering selectivity and reproducibility whilst remaining robust and affordable.

DISCUSSIONS

We have constructed a device that can measure the transmittance at different wavelengths without using the standard technique with prisms, lenses and light bulbs. Instead, we want to use high intensive multi-coloured light emitting diodes controlled by microprocessors. The measuring equipment may consist of a light source, a sample holder, a detector, a microprocessor and an LCD-display

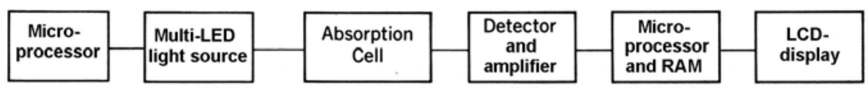

Figure 2: A simple bock diagram of the planned measurement system

The light source is made of several high-intensive light emitting diodes formed together in a cluster. The light from those diodes pass a diffusor, get focused in a convex lense and reaches a collimator which sends a parallel light beam into the sample holder. Instead of using a white light source and a prism to obtain a spectral sweep, we use five different light emitting diodes working in five different wavelengths. These are red (660 nm), green (570 nm), blue (430 nm), infra-red (880 nm and 950 nm). To determine a particular type of contaminant, we need to find the specific wavelength of the light source, at which that particular contaminant has the highest sensitivity. For example, to determine the contaminant type, A, we need to apply light source, $I_o(\lambda)$, with wavelength between λ_A and $\lambda_A+\delta\lambda$ and the concentration of the contaminants C_A is proportional to I_{tA} where : $I_{tA} = \int_{\lambda_A}^{\lambda_A+\delta\lambda} I_o(\lambda) e^{-\mu dc} d\lambda$ and for contaminant type, B, we need to apply light source, $I_o(\lambda)$, with wavelength between λ_B and $\lambda_B+\delta\lambda$ and the concentration of the contaminants C_B is proportional to I_{tB} where as : $I_{tB} = \int_{\lambda_B}^{\lambda_B+\delta\lambda} I_o(\lambda) e^{-\mu dc} d\lambda$ and so on. The value of $d\lambda$ should be experimentally determined and can be different for different contaminants.

As the current to the diodes are controlled by a microprocessor, we can get a spectral sweep according to the principles of additive colour mixing. This means that we can build a simple spectrophotometer entirely free from all kind of moving parts and fragile precision details.

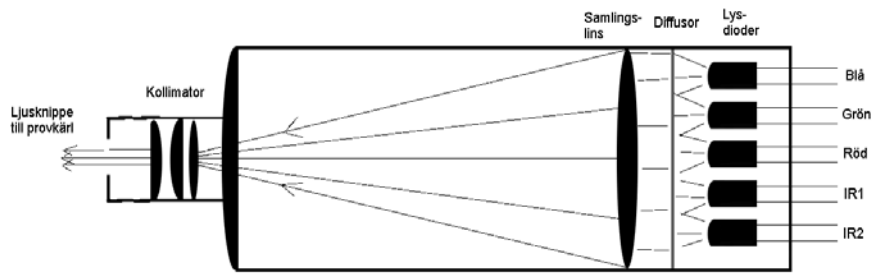

Figure 3: A proposal for the design of the light source

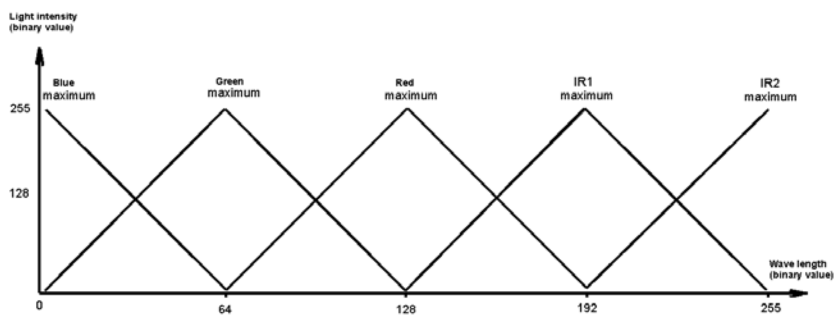

Figure 4: Change of light intensity to the different LED during the measurement.

Because both the light sources and light detectors are non-linear it is important to ensure that the measurement system remains linear. Detectors should have high sensitivity, low noise, fast response time, long time stability, and a large measurement range. Most of the modern detectors are built by semiconductors such as in the form of array of photo detectors which are sensitive at different wavelengths.

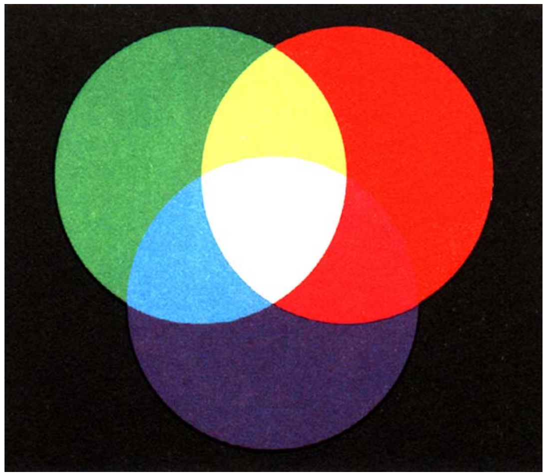

Figure 5: Additive colour mixing

One microprocessor is used to control the five D/A converters. The other microprocessor is used to generate a reset signal at a given start signal and after that generates a horizontal pulse train of 255 pulses. The hardware for the pulse generator is quite simple and a standard one as shown below.

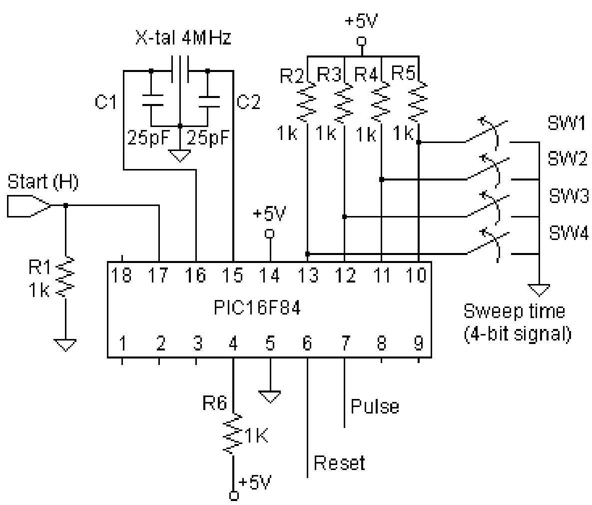

Figure 6: Pulse generator

Other types of sensors such as electronically-based biosensors which can be mass produced at low cost should also be investigated in this work to test their suitability (Brown 1999). Biosensors combine the exquisite selectivity of biology with the processing power of modern microelectronics and opto-electronics to offer powerful new analytical tools with major applications in medicine, environmental diagnostics and the food and processing industries.

CONCLUSIONS

The device presented in this work is under development and can be made robust, intelligent, and affordable for wide application in the developing countries, such as Bangladesh. The equipment has potentials to provide possibilities for continuous monitoring of air and water quality at a low cost. Such measurements will provide indicators that will help focus efforts to develop interventions. Eventual improvement of city air quality and drinking water quality is likely to require many years, and the integrated efforts of several sectors, including health, environment, energy and communication. Nevertheless, efforts to accelerate this process are likely to be rewarded with major improvements in human health.

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