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Design and Construction Fiber sensor detection system for water nitrite pollution

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Abstract:- A fiber optic sensors technique evanescent wave fiber optic sensor (EWFS) for detecting trace amounts of nitrite compounds in water was designed and constructed and evaluated for nitrite determination which based on evanescent field absorption in a test solution formed by the reaction of nitrite compounds in water with suitable chemical reagents.

A short unclad portion of a plastic clad silica fiber around (12cm) length acts as the sensing region from (20 cm) total fiber length. The absorption of the evanescent wave changes when the waist cladding refractive index n_2 is slightly modified. Consequently, the coupling visibility also changes. By putting the device in the water polluted, the trace amounts of nitrite in water can be detected. The experimental results clearly establish the usefulness of the present technique for detecting very low concentrations of the order of 1 ppb (parts per billion) of nitrite compounds with a large dynamic range of 1–1000 ppb. Such a high sensitivity enables the present device to be used for measuring the nitrite content in drinking water. The results were consistent with the data obtained by standard spectrophotometric method, showing potential of the proposed sensor for practical application.

Key word: optical fiber sensor, pollution detection, chemical fiber sensor

I. INTRODUCTION

Accurate measurement of chemical species in water has acquired great practical significance because of the toxic effects these chemicals can cause to humans. Development of simple, sensitive, low-cost, portable sensors capable of direct measurement of water pollution is of considerable interest in this context. Nitrogen compounds in water present a major health hazard and their accurate estimation is very important in the process of pollution monitoring.

The total nitrogen content of water samples can be present in many chemical forms such as nitrites, nitrates, ammonia etc. When nitrogenous matter is oxidized by the environment, the nitrogen remains mainly in the form of nitrites and nitrates. The presence of appreciable quantities of nitrite can be regarded as an indication of sewage contamination of recent origin. But nitrite is oxidized to nitrate, and consequently a large amount of nitrate points to an earlier sewage contamination [1]. The usual procedure used for the determination of nitrite levels in water is generally based on the formation of a coloured complex species on the addition of specific chemical reagents and by comparison of the intensity of colour thus formed with standards [2]. However, this method has many difficulties such as the need for complex procedures for measuring the chemicals as well as the need for large and delicate instruments. Moreover, these techniques are not sensitive to lower concentrations of the contaminant ,especially in the ppb range. Optical fiber technology offers several advantages for chemical sensing over conventional methods and hence it is worthwhile investigating the feasibility of this method to the above problem of nitrite pollution in water. In this paper, we present the details of a simple and sensitive optical fiber sensor, based on evanescent wave absorption, for measuring nitrite concentration in water ranging from 1 to 1000 ppb.

A sensor may be defined as a device that is able to indicate continuously and reversibly the magnitude of a desired measured. Optical fiber chemical sensors are offered many advantages than conventional sensors such as:

(a). Optical fiber chemical sensors can utilize many optical techniques that have been
developed for routine chemical analysis. Many of these techniques offer high specificity and sensitivity.

(b). The low attenuation of optical fibers enables the remote in-situ sensing of species in difficult or hazardous environments.

(c). The small physical size o f optical fibers allows the development of very small and flexible fiber sensors. These can be used for looking at small sample volumes or for measurements in clinical chemistry and medicine.

(d) Optical signals transmitted through optical fibers are free from electromagnetic interference. Optical fibers do not present an electrical hazard since they are non conducting and this is very important in some medical applications where fiber sensors are placed inside the patient's body.

(e) The signals from several optical fiber sensors can be multiplexed on to a single fiber and this can be linked to one signal processing unit with considerable cost savings [3].
Essentially, fiber optic sensors (FOS) work like other electrical sensors except that the FOS uses a glass fiber instead of copper wire and light instead of electricity. A FOS modulates the properties of light including intensity, phase, polarization, or wavelength shift [4]. To date, much of the instrumentation improvements in this particular application have been recorded. Different sensor applications require different types of transducers (optical fibers) to manipulate the incident radiation.

II. THEORETICAL CONCEPT

Exponentially decaying evanescent fields in the cladding region of the fiber are utilized for developing different types of intensity modulated EWFSs. In this method, evanescent wave absorption in an external medium is obtained by removing a certain region of the cladding of a fiber and allowing interaction of the evanescent field with the absorbing species in the medium. This external medium, which acts as the cladding of the waveguide, absorbs the light at the wavelength being transmitted through the fiber depending on the concentration of the species which absorbs at this wavelength. The power transmitted by an optical fiber with cladding locally replaced
by an absorbing medium is given by [8]

$$P = P(0) \exp(-\gamma CL) \qquad (1)$$

where P and $P(0)$ are, respectively, the power transmitted through the fiber with and without an absorbing medium over an unclad portion of length L. C is the concentration of the absorbing medium and γ is the evanescent wave absorption
coefficient, which is given by

$$\gamma = r_f \alpha_m \qquad (2)$$

where $r\,f$ is the effective fraction of the total guided power in the sensing region and α_m is the bulk absorption coefficient of the absorbing species. The evanescent wave absorbance is given by

$$A = Ln[P(0)/P]. \qquad (3)$$

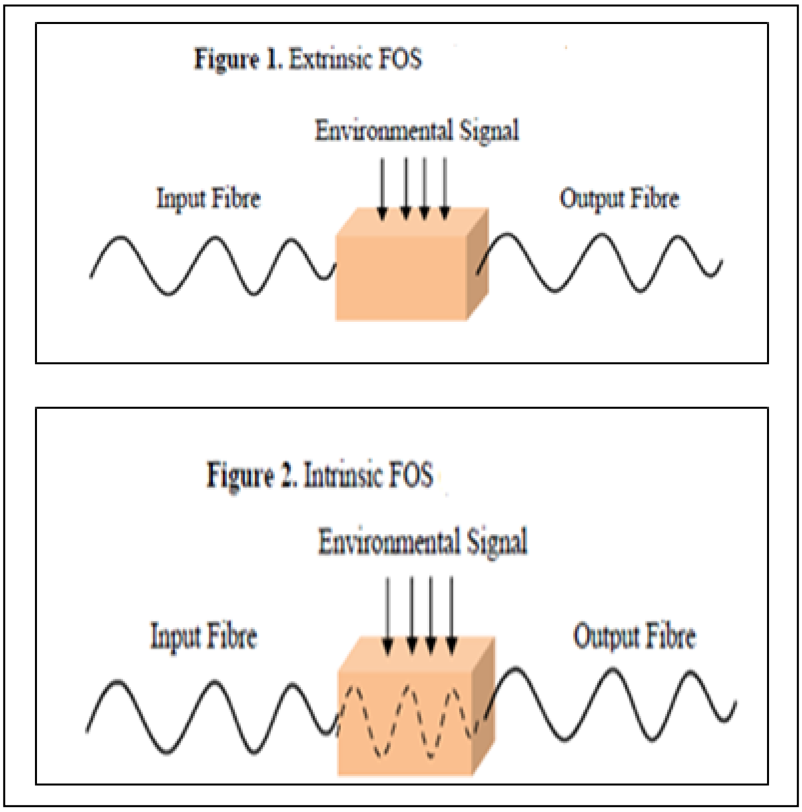
Substituting (1) and (2) into (3), we get

$$A = r_f \alpha_m CL. \qquad (4)$$

For given launching conditions, absorbing materials and the fiber, equation (4) predicts that the evanescent wave absorbance is directly proportional to the species concentration in the unclad region, the effective fraction of the total guided power in the sensing region and the length of the unclad portion of the fiber.
The same reaction, which is commonly used in colorimetric or spectrophotometric methods, is employed in the EWFS for measuring nitrite content in water [9,10].
In this reaction the nitrite ion, under acidic conditions, causes diazotization of sulphanilamide to occur, and the product is coupled with *N*-(1-naphthyl) ethylenediamine dihydrochloride to produce a violet colorations. The extent of colorations of the resultant solution is directly proportional to the nitrite concentration in water.

Fiber Sensor System Configuration
An optical fiber sensing system is basically composed of a light source, optical fiber, a sensing element or transducer, and a detector. The basic optical fiber structure consists of a core surrounded by some cladding material of a lower refractive index and both are transparent dielectric cylindrical. The requirement for FOS is to have a low optical and mechanical attenuation under all anticipated operational conditions without performance degradation [4]. FOS can be categorized into two groups: intrinsic and extrinsic. Figures (1) and (2) show a basic construction of extrinsic FOS and intrinsic FOS, respectively. So-called intrinsic devices rely on a light

beam propagating through the fiber and interaction occurs within the environmental effect and the optical fiber itself. Extrinsic fiber optic devices are where the optical fiber is used to couple light. The light beam transmits and passes out of fiber to the exposed environment effect. Then the light doubles back to the fiber again. Consequently, the light beam to and from the fiber region are influenced by the measured [5].



Fig(1) Extrinsic fiber sensor and Fig(2) Intrinsic fiber sensor.

The revolution in agricultural production brought about by nitrogen fertilizers also has a down side. The excessive use of nitrates has led to an increase in nitrate concentration in groundwater which is a major source of drinking water in many areas. Excess concentrations of nitrate in surface waters is also an indicator of agricultural or sewage pollution.

Too much nitrate in drinking water can cause a blood disorder in babies younger than 3 months. The hemoglobin in the baby's blood takes up nitrite instead of oxygen and the result is that the baby suffers severe respiratory failure. Nitrite is an intermediate oxidation state of nitrogen, both in the oxidation of ammonia to nitrate and in the reduction o f nitrate. Nitrates also act as fertilizers for aquatic plants. If rain washes nitrates out of soil into streams, rivers, lakes and then into the sea in excessive quantities, they can boost the growth of algae and other aquatic plants. This nitrate enters rivers carrying agricultural run-off and from dumping of sewage.

Many methods for the identification and quantification o f nitrates have been reported.

These can be grouped into three main categories [5,6] :

(1) Visible Colorimeter following reagent addition.

(2) Direct absorbance measurements.

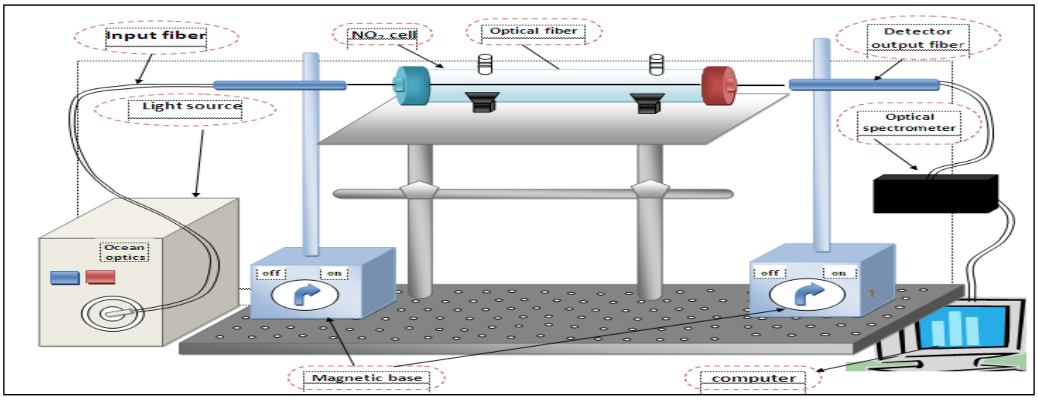
(3) Ion Selective Electrodes.

The optical fiber sensor is used the second method for monitoring the nitrat concentration in water. The main concept of this sensor is the evanescent wave.

III. EXPERIMENTAL CONCEPT:

In order to exploit the evanescent waves in the multimode fiber ,a known length (12 cm) of the cladding of a plastic clad silica (PCS) fiber of 200 μm core diameter (200/380 μm) is chemically removed. A sensor cell of 20 cm length is designed to hold the water samples containing nitrite. It is made of a cylindrical glass tube having a diameter of 4 cm with inlet and outlet provisions. The optical fiber is introduced into the glass tube through the holes provided at the two ends so that the unclad portion of the fiber is within the glass tube and remains straight. The experimental set-up used for the present investigation is shown in figure 1. The

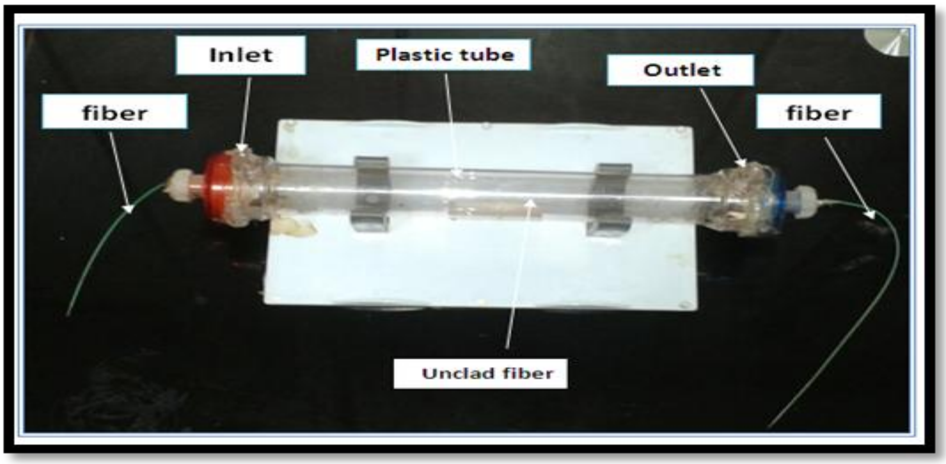
output from an intensity stabilized (the maximum drift with respect to mean power level measured over 2 h is ±0.5%) green He–Ne laser (JDS Uniphase) emitting at 543.5 nm is coupled to one end of the fiber using a microscope objective having the same numerical aperture. The light emerging from the other end of the fiber is fed to a light detector unit (Digital Power Meter 45-545, Metrologic make) which digitally displays the detected optical power. Standard water samples having nitrite concentrations ranging from 1 to 1000 ppb are prepared by dissolving sodium nitrite in water. Then sulphanilamide solution is added and after 5 min *N*-(1-naphthyl) ethylenediamine dihydrochloride solution is added to each of the repared sample solutions such that the ratio between the water samples and the two reagents are 50:1:1, respectively. Now, the colour of the test solution becomes violet and its colour intensity varies with nitrite concentration. These test samples are then allowed to remain for 10 min to complete the reaction, after which the measurements are carried out. When the unclad portion of the fiber is immersed in the test solution, the evanescent field penetrates into the liquid and interacts with it. Since the wavelength of light passing through the fiber is almost close to the peak absorption wavelength of the solution, strong evanescent wave absorption occurs and it increases with the increase in nitrite concentration.
To investigate the feasibility of using optical fibers for sensing of nitrates in water the experimental set-up shown in fig(3).



Fig(3):The experimental set up for sensing the concentration nitrat in water.

The experimental set up was contend a UV light from a Deuterium lamp is coupled to the optical fiber by FC connecter and this fiber is used to guide UV light to the absorption cell. The second end of the fiber takes light from the absorption cell to the digital power meter detector the model(Lambda LLM-3 light power meter) and spectrometer model(HR 2000 high-resolution spectrometer Ocean Optics.com). The spectrometer was connected to personal computer .The light intensity levels as a function of wavelength was recorded.

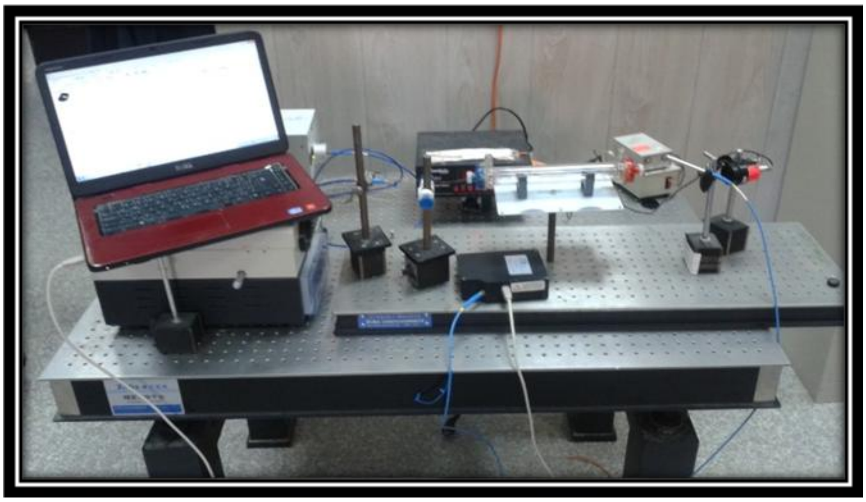
The optical fiber was prepared for the sensing. The multimode fiber, a known length (12 cm) of the cladding of a plastic clad silica (PCS) fiber of 200 μm core diameter (200/380 μm) is chemically removed. A sensor cell of 20 cm length is used to hold the water samples containing nitrite. It is made of a cylindrical Plastic tube having a diameter of 4 cm with inlet and outlet The optical fiber is introduced into the plastic tube through the holes provided at the two ends so that the unclad portion of the fiber is within the plastic tube and remains straight is shown in fig(4).



Fig(4) The plastic cell for contains the water sample.

The experimental set-up Photograph used for the present investigation is shown in fig(5).

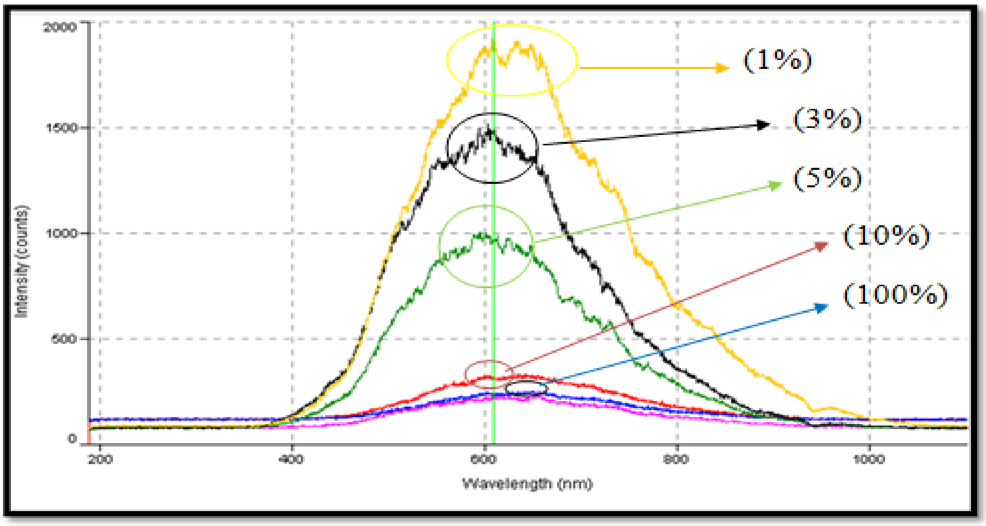
Fig (5) : The photograph for experimental setup work.



Standard water samples having nitrite concentrations ranging from (1 ml – 100 ml) are prepared by dissolving sodium nitrite in water. Then sulphanilamide solution is added and after 5 min *N*-(1-naphthyl) ethylenediamine dihydrochloride solution is added to each of the prepared sample solutions such that the ratio between the water samples and the two reagents are 50:1:1, respectively. Now, the colour of the test solution becomes violet and its colour intensity varies with nitrite concentration. These test samples are then allowed to remain for 10 min to complete the reaction, after which the measurements are carried out. When the unclad portion of the fiber is immersed in the test solution, the evanescent field penetrates into the liquid and interacts with it. Since the wavelength of light passing through the fiber is almost close to the peak absorption wavelength of the solution, strong evanescent wave absorption occurs and it increases with the increase in nitrite concentration.

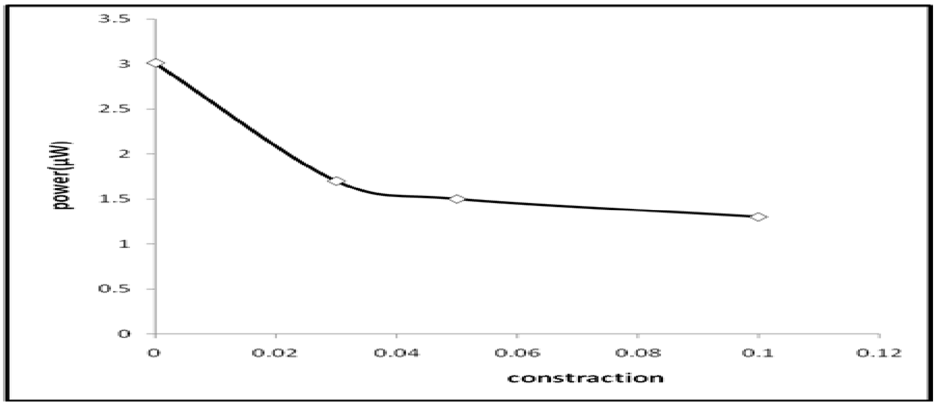
IV. RESULTS AND DISCUSSION

Figure 6 shows the Intensity spectra of water samples containing different nitrite concentrations in the wavelength range 200–1200 nm recorded using a commercial spectrometer (HR 2000 high-resolution spectrometer Ocean Optics.com). Then Intensity peak of the spectra is at around 595 nm and the intensity of light passing through the solution decreases with the concentration of the colored constituent in the solution.



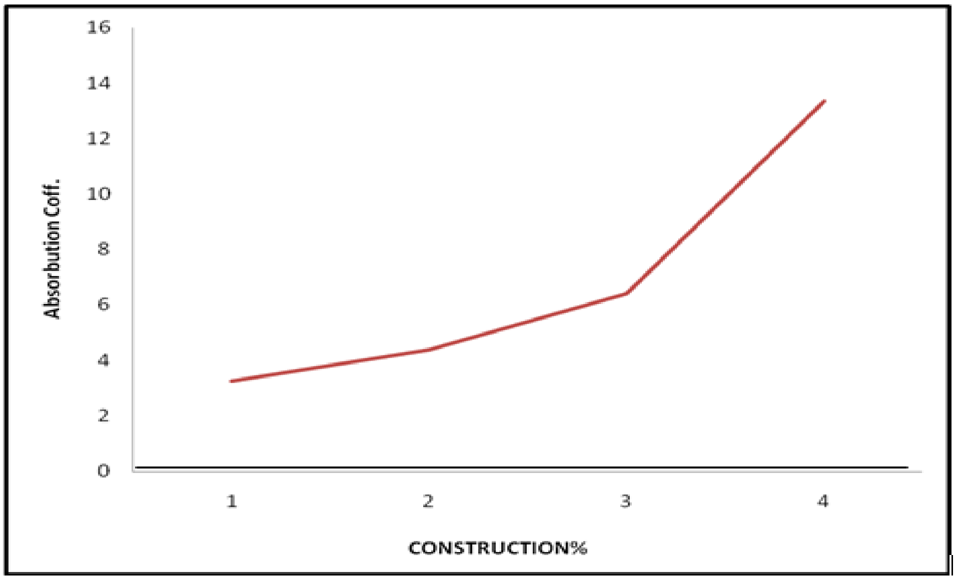
Figure(6). Intensity absorption spectra of water samples containing different nitrite concentrations obtained from the spectrometer.

Figure7 shows the maximum power of tested sample as function to nitrite concentrations within the range 3%–100% at the peak absorption wavelength.



Figure(7) The relation between the nitrite construction and maximum power.

Figure8. The variation of the evanescent wave absorbance with concentration at the peak absorption wavelength (595 nm) by using the equation (3).



Fig(8) **The variation of the evanescent wave absorbance with nitrate concentration.**

Figure(8)shows the variation of the evanescent absorption coefficient with concentration using white light as the source instead of a laser. In this case, light from a 0.1mW tungsten halogen lamp is coupled to one end of the fiber. At the other end, the light from the fiber is focused onto power meter . Here the nature of the graph is the same as that of figure 6, but the dynamic range is considerably limited. It may be noted that in the absorption increases steeply beyond 1000 ppb, presumably due to the formation of strongly absorbing aggregates and complexes in the solution, which significantly alters the optical properties of the medium [10].

V. CONCLUSIONS

A fiber optic sensor system depending upon evanescent wave fiber optic sensor (EWFS) technique have designed and developed for sensitive measurement of trace amounts of nitrite content in water .ranging from 1 to 1000 ppb.

EWFS powered by a laser source and EWFS with a white light source. Experimental results demonstrate the usefulness of EWFSs in measuring nitrite compounds in water with good sensitivity in the lower concentration range. This establishes that the system can be used for measuring the nitrite content in drinking water and for monitoring the water quality in wells near to fertilizer plants and sewage systems.

REFERENCES

[1] W.A. Chudyk and J. Kenny, “Monitoring of Groundwater Contaminants using Laser Fluorescence and Fiber Optics” , Intech, 53, (May 1987).

[2] L.A. Eccles. “In-Situ Monitoring at Superfund Sites with Fiber Optics”. United States Environmental Protection Agency, EPA/600/X-87/156, (June 1987).

[3] T. Maugh, “Remote Spectrometry with Fibre Optics” , Science, Ybl. 218, 875, (1982).

[4] M. Saull, “Nitrates in Soil and Water” , New Scientist, Inside Science Supplement No. 37, (15 September 1990).

[5] Guptha B D and Khijwania S K 1998 Experimental studies on the response of the fibre optic evanescent field absorption sensor *Fibre Integr. Opt.* **17** 63–73.

[6] MacCraith B D 1998 Optical fiber chemical sensor systems and devices *Optical Fiber Technology* vol 4, ed K T V Grattan and B T Meggitt (London: Kluwer) ch 2.

[7] Guptha B D, Singh C D and Sharma A 1994 Fibre optic evanescent field absorption sensor: effect of launching condition and the geometry of the sensing region *Opt. Eng.* **33** 1864–8250.

[8] Johnson K.S. and Coletti, L.J., 2002, In situ ultraviolet spectrophotometry for high resolution and long-term monitoring of nitrate, bromide and bisulfide in the ocean: Deep Sea Research, v. 49, p.1291–1305.

[9] Lee T, Nibu A G, Suresh Kumar P, Radhakrishnan P, Vallabhan C P G and Nampoori V P N 2001 Chemical sensing with microbend optical *Opt. Lett.* **26** 1541–3

[10] MacCraith B D 1998 Optical fiber chemical sensor systems and devices *Optical Fiber Technology* vol 4, ed K T V Grattan and B T Meggitt (London: Kluwer) ch 2 ,250