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A SURVEY ON WIRELESS SENSOR NETWORKS APPLICATION FOR AIR POLLUTION MONITORING

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Abstract: *As the countries become industrialized, the pollution level to our environments increases and this pollution becomes a major problem for the health of the population and also affects the ecosystem. Although some standards are set with environmental authorities for wastes emissions in air, the monitoring and controlling of that standards are still a challenge in most industries especially chemical industries and cement factories. To avoid such adverse imbalances in the nature, an air pollution monitoring system is utmost important. Some of the pollution monitoring systems in cement factories are OPSIS, Uras26, Magnos27 and CODEL. These systems are installed to monitor the emissions from chimney only. Wireless Sensor Networks is an excellent technology that can sense, measure, and gather information from the real world and based on some local decision process it transmit the sensed data to the user. These networks allow the physical environment to be measured at any point, and greatly increase the quality of the environment. This paper reviews the importance of employing wireless sensor networks in air pollution monitoring in cement factories along with their advantages and disadvantages*

Keywords: Air pollution, wireless sensor network, Uras26, Opsis, CO & SO2 detection.

1. INTRODUCTION

Air pollution is the presence of contaminants or pollutant substances in the air that interfere with human health or welfare, or produce other harmful environmental effects [1]. These pollutant substances usually result from vehicle emissions, Industrial emissions and volatile organic compounds. The health issues caused by air pollutants are difficulty in breathing, coughing and aggravation of existing respiratory and cardiac conditions. The World Health Organization states that 2.4 million people die each year from causes directly attributable to air pollution, with 1.5 million of these deaths attributable to indoor air pollution [2]. Based on the fact mentioned above, the human should focus on air pollution monitoring.

With the rapid development of communication technology, network technology and remote sensing technology, there is a trend that air pollution monitoring system is often designed in wireless mode. At present, the wireless mode in air pollution monitoring system includes GSM, GPRS, etc. But these modes are expensive on both installation and maintenance, and complexity. On the other hand, Wireless sensor network have been rapidly developed during recent years. Initially it was for military and industrial controls [3]. Its advantages may include the liability, simplicity, and low cost. Based on these advantages, it is now being applied in environmental monitoring issues.

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, and to cooperatively pass their data through the network to a main location. . The wireless protocol you select depends on your application requirements. Some of the available standards include 2.4 GHz radios based on either IEEE 802.15.4 or IEEE 802.11 (Wi-Fi) standards[4].

Engineers have created WSN applications for areas including health care, utilities, and remote monitoring. In health care, wireless devices make less invasive patient monitoring and health care possible. For utilities such as the electricity grid, streetlights, and water municipals, wireless sensors offer a lower-cost method for collecting system data to reduce energy usage and better management of resources.

Remote monitoring covers a wide range of applications where wireless systems can complement wired systems by reducing wiring costs and allowing new types of measurement applications.

Remote monitoring applications include:

- Environmental monitoring of air, water, and soil
- Structural monitoring for buildings and bridges
- Industrial machine monitoring
- Process monitoring
- Asset tracking

2. LITERATURE REVIEW

Henrik Madsen et al in 2004 introduces a computer aided modeling and pollution control tool (called PoLogCem –

Pollution Logistic Cement)[5], with the following functionalities:

- The achievement for representatives' mathematical models for the environmental pollution process
- The monitoring of the production process with pollution influence
- The searching for the optimal solutions for production planning, which minimize pollution effects

They integrated three principal modules (i.e statistical modeling module, measurement management module and optimization module) in order to obtain a software architecture that is easy to manipulate and maintained. The module designed for modeling stage is able to assist the end user in experimentally determining the parameters of the environment pollution. Also a logistic module provides reports for monitoring the pollution level and the contribution of each specific item of equipment to the pollution level. The software system, called PoLogCem, is specially designed in order to scan the pollution activity specific for cement plants and to find logistical solutions with the purpose of pollution control in the cement industry.

In 2012, Amnesh Goel et al.[6] proposed a wireless sensor network to monitor air pollution levels of various pollutants due to environment changes. A wireless network is comprises of large number of sensors nodes. This system proposes a method which mainly focuses on longer sustain time period of sensor network by effectively managing energy in sensor network, effectively processing of collected information and less overhead in transferring information between various sensor nodes.

In 2011, Wenhu Wang, et al.[7] in order to comply with requirements of oil and gas industry, an air quality monitoring system was proposed based on ZigBee wireless sensing technology. It uses ZigBee wireless network to send results to the monitoring center so that, if some abnormal situations happens, a quick warning will be generated to remind staff to take effective measures to prevent major accidents and protect human lives in industry.

Kavi K. Khedo et al in 2010 [8] proposed an innovative system named Wireless Sensor Network Air Pollution Monitoring System (WAPMS) to monitor air pollution in Mauritius through the use of wireless sensors deployed in huge numbers around the island. In order to improve the efficiency of WAPMS, they have designed and implemented a new data aggregation algorithm named Recursive Converging Quartiles (RCQ). The algorithm is used to merge data to eliminate duplicates, filter out invalid readings and summarize them into a simpler form which significantly reduce the amount of data to be transmitted to the sink and thus saving energy. For better power management they used a hierarchical routing protocol in WAPMS and caused the motes to sleep during idle time.

3. THE CONCENTRATION OF THE GASES IN THE ATMOSPHERE AND THEIR CHEMICAL REACTIONS

3.1 Carbon Monoxide

Carbon monoxide, CO is formed when combustion of carbon based materials take placed and there is not enough oxygen to create carbon dioxide. It is a product of imperfect combustion of hydrocarbon fuels (such as oil, gasoline, natural gas, and coal) and is almost always formed to some degree when something is burned because burning anything never results in perfect combustion. On an industrial scale however, carbon monoxide is formed in a completely different reaction, known as steam reformation. In this process methane gas (also known as natural gas) is combined with steam (gas phase water) at high temperature over a catalyst to form hydrogen gas and carbon monoxide [9]:

$$CH_4 + H_2O \text{ --> } 3H_2 + CO \quad (1)$$

CO is little lighter than air and is easily blended with it. Its solubility in water is little greater than that of air. CO creates an explosive gas mixture with air at a content of 12-75 % [9]. Carbon monoxide is dangerous because it inhibits the blood's ability to carry oxygen to vital organs such as the heart and brain. Inhaled CO combines with the oxygen carrying hemoglobin of the blood and forms carboxyhemoglobin (COHb) which is unusable for transporting oxygen. The figure below show health effects of various concentration of carbon monoxide [10]

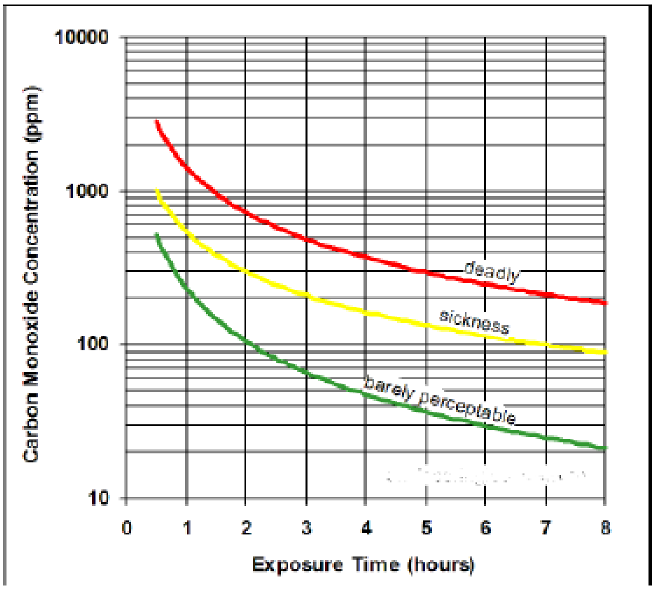

Fig. 1 Health effects of various concentration of carbon monoxide

3.2 Sulphur Dioxide

Sulphur dioxide is produced when fuels containing sulfur are burnt and when ores of Copper (Cu), Lead (Pb) and Zinc (Zn) are smelted. They affect human health through the respiratory system causing reversible bronchial constriction at concentrations as low as 1.6 ppm. Asthma patients begin to feel the breathing problems at a concentration of 0.5 ppm. Permanent lung damage at concentrations of 20.0 ppm. SO2 has a pungent irritating smell at about 3.0 ppm which is the smell ‘detection limit’[11]. Sulfur dioxide go through several complex steps of chemical reactions before they become the acids found in acid rain. Sulfur dioxide reacts with moisture found in the atmosphere. When this happens, sulfate dioxide immediately oxidizes to form a sulfite ion [11].

$$SO_2(g) + O_2(g) \dashrightarrow SO_3(g) \quad (2)$$

Afterwards, it becomes sulfuric acid when it joins with hydrogen atoms in the air

$$SO_3(g) + H_2O(l) \dashrightarrow H_2SO_4(aq) \quad (3)$$

This reaction occurs quickly, therefore the formation of sulfur dioxide in the atmosphere is assumed to lead this type of oxidation to become sulfuric acid[12].

4. POLLUTION MONITORING SYSTEMS IN CEMENT INDUSTRIES

In Cement factory, the systems which are used to monitor the amount of wastes emitted into air mostly are OPSIS, Uras26, Magnos27 and CODEL which are all wired systems and they monitors the emissions passing through the chimney only. So the emissions from other areas are not monitored. Also these systems are more expensive, so most factories fails to install these systems. This situation makes difficult for the Environment Management Authorities to know exactly the amount of pollution emitted to our environment. The figure below shows the areas where gas analysers are fixed.

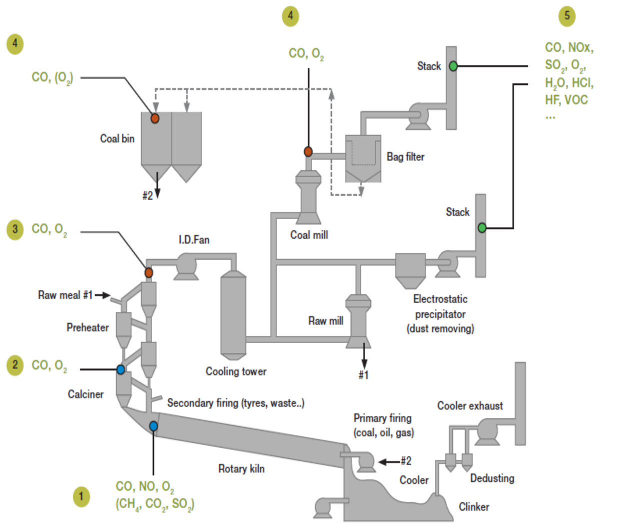

Fig.2 Gas analysis in cement industry [13]

4.1 URAS 26

The measurement principle of the Uras is based on the capability of gas molecules to specifically absorb infrared (IR) radiation. This means that energy is removed from a light beam within a certain frequency range, depending on the gas concentration. In most infrared gas analyzers a photo detector is used to detect this effect. It contains gas-filled, so-called "opto-pneumatic" detectors, in which the sample of interest is held. The radiant energy absorbed by the filled gas causes a change in temperature and thereby a change in pressure in the detector. This change in pressure evokes an electrical signal via a membrane capacitor. The correlation between the gas detector and the sample gas provides an extremely high selective sensitivity with regard to gases such as CO, CO_2, SO_2, NO, CH_4 and N_2O.

In the Uras26, the concentrations of up to four process gas components can be reliably determined by connecting detectors in series. The length of the sample cells installed upstream of the detectors determines the provable concentrations, which range from a few parts per billion by volume (ppbv, <10–5 % Vol.) to 100 % Vol. The Uras26 also has integrated calibration cells, which automatically move into the optical beam path [13]. These supply a reference signal and ensure long-term stability. Maintenance costs are reduced because built-in calibration dispenses with the need for expensive test gas cylinders. A low-noise measurement is provided by periodic modulation of the IR radiation source with an interrupter disk ("chopper wheel") and subsequent frequency – and phase - selective amplification. This type of signal processing is generally referred to as a "lock-in" process[14].

4.2 OPSIS GAS ANALYSER

The Opsis AR 600 Analyser is the central unit of an Opsis Continuous Emissions Monitoring system. It accepts light from one or more light paths via a fibre optic cable and provides data for presentation through Opsis software. It also includes a modem, allowing data to be uploaded to a remote PC and allowing remote supervision and adjustment [15]. An Opsis system consists of a light source, a receiver, an opto-fibre, and an opto-analyser. The analyser consists of a spectro-meter, a detection system, electronics for the operation of the grating, etc., and a computer for the evaluation and signal processing.

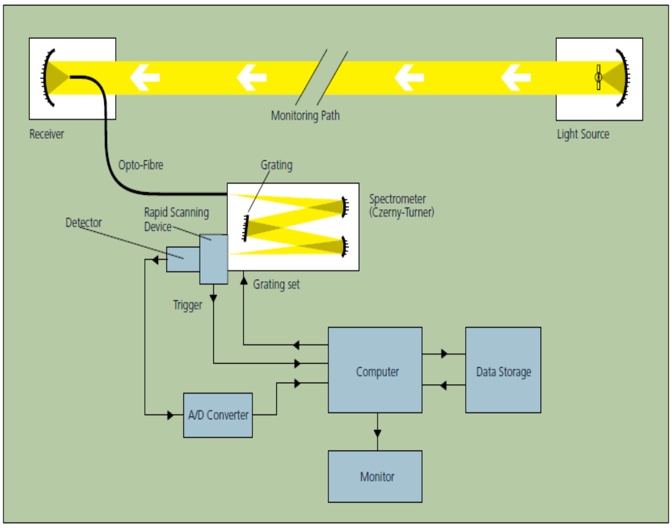

Fig. 3 Structure of opsis gas analyser [15]

4.2.1 The monitoring path

The positioning of the emitter and the receiver define the monitoring path. The light source in the emitter is a high-pressure xenon lamp. This type of light source radiates an almost smooth spectrum ranging from approximately 200 nm up to 500 nm, and from about 1200 to 1800 nm. Within these ranges a number of gaseous substances show specific absorption spectra. The lamp spectrum is however not perfectly smooth, but the remaining "hills" in the spectral output are being taken care of in the evaluation.

The emitted light beam is directed towards the receiver, and on its way the intensity is affected by scattering and absorption in molecules and particles. From the receiver the captured light is led via an opto-fibre to the analyser. The function of the fibre is only to avoid exposing the opto-analyser to dust, high humidity, temperature variations, etc.

4.2.2 The opto-analyser

When the light reaches the analyser, it enters a spectrometer. Inside the spectrometer, a grating refracts the light into its wavelength components. The refracted light is then projected onto a rapid scanning slit in front of a photo- multiplier detector or an infrared sensitive diode, where a selected part of the spectrum is detected. The scanning slit device makes it possible to record all wavelengths separately, although only one detector is used.

As the grating is moveable, any chosen part of the spectrum can be detected. The wavelength window can thus be optimized for a certain component, with respect to parameters such as sensitivity and interfering pollutants. Approximately 100 scans per second are recorded.

The current from the detector is converted into digital signals by a 12 bit analog to-digital converter, and the signal is stored and accumulated in a multi-channel register. The detected spectrum is typically 40 nm wide in the Ultraviolet (UV) range and approximately twice as wide in the infrared (IR) range. Each scan is digitized into 1000 points.

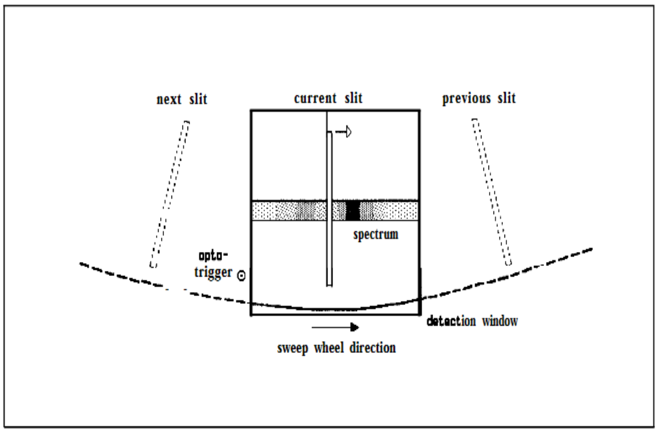

Fig. 4 Schematic drawing of the exit window and the scanning slit in the spectrometer.

The detector's "eye" covers the whole window. Due to turbulence in the air the recording time for one spectrum has to be in the order of 10ms. A fixed slit is thus not applicable. A slotted disk, rotating with about 300 rpm, provides the detection system with the required time resolution. The opto-trigger signal is used by the computer to prepare the multi-channel memory for a new scan, and to reset the analogue-to-digital converter

5. THE ADVANTAGES AND DISADVANTAGES OF WIRELESS SENSOR NETWORKS

Advantages:

- Network setups can be done without fixed infrastructure.
- Ideal for the non-reachable places such as across the sea, mountains, rural areas or deep forests.
- Flexible if there is ad hoc situation when additional workstation is required.
- Implementation cost is cheap.

Disadvantages:

- Less secure because hackers can enter the access point and get all the information.
- Lower speed compared to a wired network.
- More complex to configure than a wired network.
- Easily affected by surroundings (walls, microwave, large distances due to signal attenuation, etc.).

6. CONCLUSION.

Although some standards are set with environmental authorities for wastes emissions in air, the monitoring and controlling of that standards are still a problem in most industries especially cement factories. In Cement factory, the systems which are used to analyses the amount of wastes emitted into air mostly are Opsis and Uras26 which are all wired to personal computer (PC) based. Since these systems monitor the emissions from the chimney only, emissions from other areas close to the factories are not monitored. Also these systems are more expensive, so most factories fails to install these systems. This situation makes difficult for environmental authorities to know exactly the amount of pollution emitted to our environment. Due to above situations, there is a need for employing WSN systems for monitoring air pollution in cement industries since it is easy to install to all areas where there is emissions of wastes to the environments.

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