RESEARCH ARTICLE OPEN ACCESS

Intelligent Monitoring System For Carbon Monoxide Poisoning And Leakage In Mines

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Abstract-
This paper presents a feasibility study of a wearable helmet in order to protect mine workers specially of goldmines from carbon monoxide poisoning and cyanidation. Carbon monoxide(CO) poisoning is a common problem faced by the workers of coal, gold and many other mines. On the other hand cyanidation problem occurs in gold mines only during ore processing. Current safety systems for mine workers, only monitors environmental concentrations of gas. This is insufficient because toxic exposures effects people at different levels based on their immunity levels. During mining process CO can be emitted which is a odorless gas and lighter than air, it cannot be sensed by workers and effects the hemoglobin range in the body so a CO gas sensor is implemented here in order to detect CO, if the density of CO exceeds inside the mines then the exhaust fan can be switched ON automatically. The key feature of this system is pulse oximetery sensor which will be checking the health parameters of each and every person employed there. During ore processing sodium cyanide is added to the ore in order to extract the gold from its ore which is a acidic substance. If acidity increases beyond a certain level then system will automatically pump sodium hydroxide into the ore to make it less acidic. All these three parameters will be displayed on LCD in the central location which will contain buzzer also for emergency. So in this system we are monitoring three parameters of workers as compare to one in previous systems and hence the security of workers is enhanced.
Keywords- Cyanidation; Pulse oximetery.

I. INTRODUCTION

Recently many incidents have been reported of CO poisoning, leading to the death of many workers in the mines[1]. Some workers even tried to ventilate the areas in the mine but that was not sufficient[2]. Common symptoms of CO poisoning are headache, fatigue and muscle ache.

The current safety systems are inefficient because environmental monitoring alone is not able to save a person who is daily smoker , or person who has reduced RBC count. The system implemented in this paper can improve the safety of mine workers to greater extent.

Here we are going to fix Pulse oximetery in the person's wrist which will check the hemoglobin concentrations of the wearer. We have conducted this study using a oximetery sensor which will monitor the pulse of the person and give readings continuously in real time on the LCD in the central location.

II. RELATED WORK DONE

CO is colorless and odorless gas which is toxic in nature . CO forms bonding with the hemoglobin in our blood and forms a compound named as carboxyhemoglobin due to which normal oxygen transport in our blood is interrupted and which can lead to death.

The effects of carbon monoxide vary with its internal concentrations, at 30% blood saturation headache, fatigue, and fainting occurs. At higher levels, approaching 60%, a person will become unconscious and if not rescued, continued exposure will result in death [5]. Pulse oximetery is used to monitor the hemoglobin concentration, which is a application of Beer's Law. which relates the attenuation of light through a medium dependent upon the compounds it passes through [4]. In pulse oximetery light emitted passes through vascular tissues of body, it is absorbed at different rates and frequencies by the hemoglobin of each and every person. Different wavelength of light is required for each person. The pulse oximeter is composed of LED's and photodiode. LED's will emit light of various wavelength and that will be received by photodiode in oximeter. There are two types of geometrical configurations between LED and Photodiode. One is called as transmissive and other one is called as reflective. For transmissive design passes through the body where as in the reflective design it is reflected inside the body e.g. from bones and then received by the photodiode. Here in this system reflective type pulse oximeter is used. Pulse oximetery shows volumetric changes of the blood in the form of graph called photopleysmograph (PPG).The Values of this graph rise and falls according to the heart beat. When heart pumps blood then an peak appears in the graph. Here error can occur when person moves from one place to other. Because volume of blood at the place of measurement can change due to the movement of the body[10].

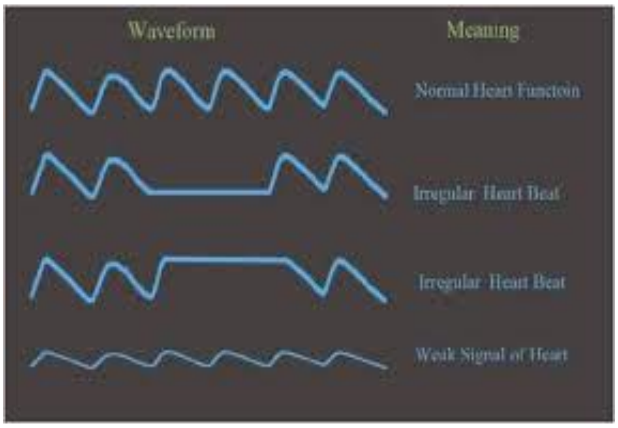


Fig. 1. Pulse oximeter output in different cases.

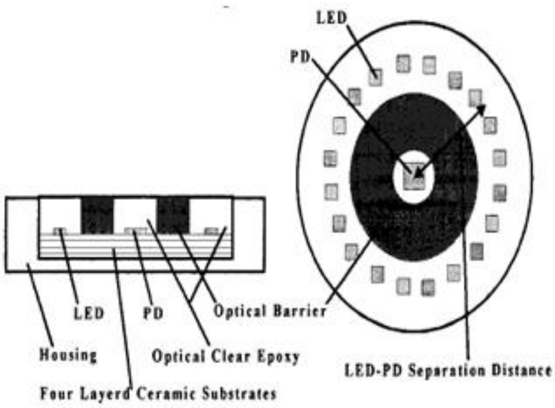
III. SENSORS USED IN HELMET

In this system the helmet will be containing three sensors which will be protecting workers inside the mine in all respects. Hence providing additional security or protection to the workers. The sensors used here are:

A. Pulse Oximetery

As explained earlier in previous sections, this sensor
will detect the level of oxygen in our blood and calculate heart beat of the person by counting the number of peaks present in the graph called photopleysmograph. Here in this system it is done by sending light waves of different wavelengths into the body which will be then reflected by the bones or some other parts inside the body and finally will be received by photodiode present inside the sensor[12].

Normally photodiode chip is present at the centre of the pulse oximeter, which is surrounded by the optical barrier in order to protect it from direct contact between LED's and photodiode. To increase the pulsatile signal level and to decrease the tissue in homogeneity level ten LED chips are used for each wavelength and hence total twenty chips are used which are placed in systematic order at an equal radial distance of 7mm around the photodiode[12].



Side view Top view

Fig. 2. A reflectance pulse oximetery sensor with diameter 23mm and thickness being 6.7mm[12].

The LED should be much brighter as the light is to pass through finger and detected back by the photodiode. Now, when the heart pumps the blood during heart beat through the veins, the finger becomes much more opaque and so less light will pass through the detector. With each heart pulse the detector signal varies. This variation is converted to electrical pulse which is amplified and triggered through an amplifier which gives output of +5 volts[12].
The values of the heart beat of the person will be displayed in LCD present at the central location (receiver section). By continuously checking these values one can easily come to know when an person is suffering from the CO poisoning as his number of heart beats will be reduced significantly.

B. Gas Sensor

Sensors are required in the mines or construction sites to detect methane and carbon monoxide. Because leakage of methane can cause explosion where as leakage of CO can cause poisoning to the workers in the mine. One more gas which can breakout in mines is hydrogen and is able to cause explosion in the mines but probability of hydrogen breakout is lesser as compare to previous two.
Gas sensor measures the concentration of gas in its vicinity. Gas sensor interacts with a gas to measure its concentration. Each gas has a unique breakdown voltage i.e. the electric field at which it is ionized. Sensor identifies gases by measuring these voltages. The concentration of the gas can be determined by measuring the current discharge in the device[14][15].
Various gas sensing technologies are:

- Metal Oxide Based Gas Sensors
- Capacitance Based Gas Sensors
- Acoustic Wave Based Gas Sensors
- Calorimetric Gas Sensors

- Optical gas sensors
- Electrochemical gas sensors

In this system we are using electrochemical gas sensor MQ-2 which is analog in nature. In 1950 analog sensors were used only for oxygen monitoring. In mid 1980's we start using them for detecting poisonous gases[16].

Principle of operation of electrochemical sensor

These sensors react with the gas of interest and produce an electric signal proportional to the concentration of the gas. It made up of sensing electrode and counter electrode which is separated electrolyte layer, as shown in fig.3 [17][18].

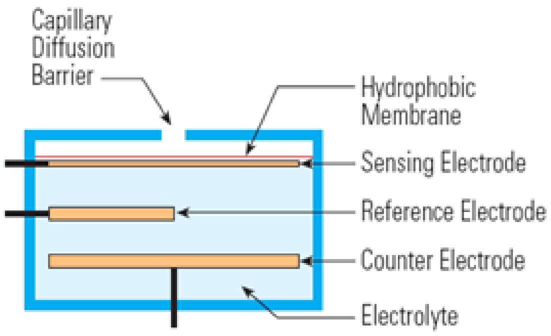


Fig. 3 Electrochemical sensor set up[17][18]

When gas leaks out it will come in the contact of the sensor and passes through a small capillary-type opening and then diffuses through the electrode surface. This allows gas to react at the sensing electrode and produce sufficient amount of electrical signal. It also prevents the leakage of electrolyte from the sensor, as shown in fig.3.When the gas enters through the barrier and reacts with sensing electrode then either oxidation or reduction takes place over there. Electrode material is used to catalyze these reactions. By using a resistor across the electrodes, a current will start to flow between anode and the cathode which is proportional to the gas concentration. This current can be measured to determine the gas concentration. Because of this current generated, the electrochemical sensor is often called as an amperometric gas sensor or a micro fuel cell. For a sensor requiring an external driving voltage, having a stable and constant potential at the sensing electrode is important. The potential of the sensing electrode does not remain constant due to the continuous electrochemical reaction which is taking place on the surface of the electrode. Which leads to deterioration of the performance of the sensor over extended or longer periods of time. Reference electrode is used to increase the performance of the sensor. This is placed within the electrolyte near to sensing electrode. Fixed voltage is maintained at the sensing electrode with the help of reference electrode. No current flows to or from the reference electrode. Current flows between the sensing and the counter electrode due to the reaction of gas molecules on the sensing electrode. This current is measured and is related directly to the gas concentration. The sensor is targeted toward specific gas by voltage value applied at the sensing electrode[17][18].

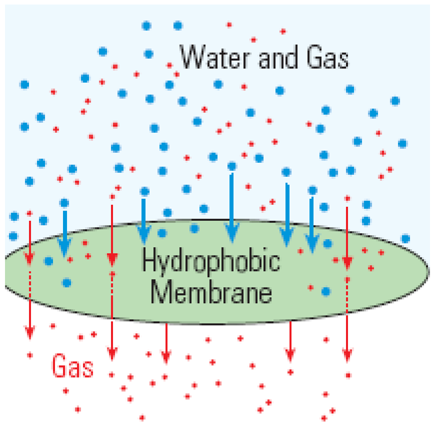


Fig.4 removal of water by hydrophobic membrane

The electrochemical sensor which we are using in this system is MQ-2 which is analog in nature. This sensor has sensitivity to methane, propane, hydrogen and CO.

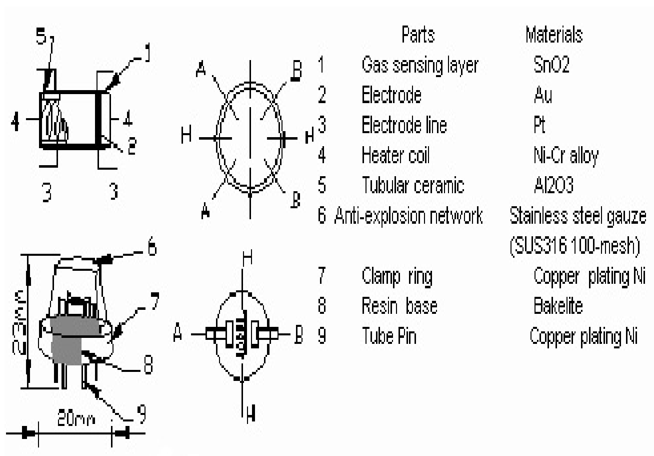


Fig. 5 Basic structure of MQ-2

Sensing material of this sensor is SnO_2, which is having less conductivity in clean air, which increase with increase in the concentration of target gas in air. We are using this sensor here because it is more sensitive, having long life, fast response and low cost. The structure and configuration of MQ-2 is shown in Fig. 5.

In this system the sensor is interfaced to the microcontroller in such a way that once gas is detected by it, the exhaust fan in the mine will be started automatically and in the receiver section (central location) buzzer will blow. And the amount of gas present in the place will be displayed on the LCD.

Technical Specifications

All technical specifications of MQ-2 is given in the table no. 1.

Table.1. Technical Specifications[19]

Model No.			MQ-2
Sensor Type			Semiconductor
Standard Encapsulation			Bakelite (Black Bakelite)
Detection Gas			Combustible gas and smoke
Concentration			300-10000ppm (Combustible gas)
Circuit	Loop Voltage	V_c	≤24V DC
	Heater Voltage	V_H	5.0V±0.2V ACorDC
	Load Resistance	R_L	Adjustable
Character	Heater Resistance	R_H	31Ω±3ΩRoom Tem.
	Heater consumption	P_H	≤900mW
	Sensing Resistance	R_s	2KΩ-20KΩ(in 2000ppm C_3H_8)
	Sensitivity	S	Rs(in air)/Rs(1000ppm isobutane)≥5
	Slope	α	≤0.6($R_{5000ppm}/R_{3000ppm}$ CH_4)
Condition	Tem. Humidity		20±265%±5%RH
	Standard test circuit		Vc:5.0V±0.1V V_H: 5.0V±0.1V
	Preheat time		Over 48 hours

C. pH Sensor

The third feature of the system present in this paper is pH sensor. pH sensor will check the acidity of the soil or ore during extraction of gold. If any how it is acidic then automatically pH sensor will sense that and turn the DC motor on which will spray the sodium hydroxide on the soil or ore to neutralize it. Values of all the sensors will be sent to central location through zigbee and will be displayed in the LCD present over there. pH is a unit of measure which is used to describe the acidity level of a solution and is measured on the scale of 0 to 14[20]. Actually it is the negative logarithmic of the hydrogen ion activity. pH is given by -log[H+]. If concentration H+ ions is higher than OH- ions then the material is acidic in nature. If the OH- concentration is higher than the material is basic in nature. 7 is considered as neutral, <7 is acidic, >7 is basic on the pH scale[20].

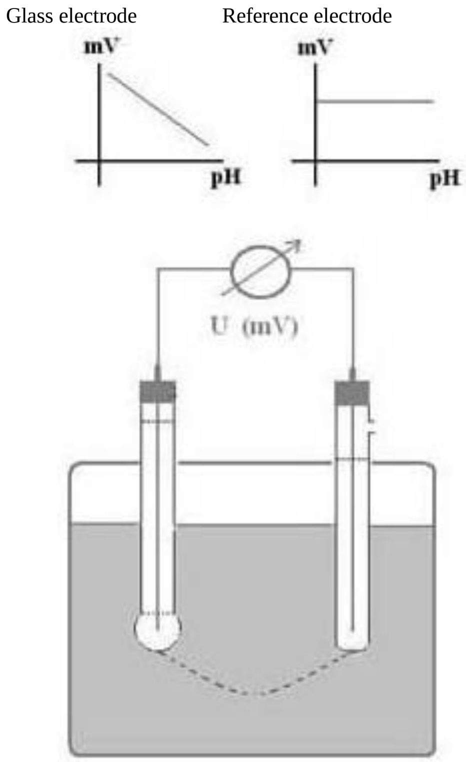


Fig.6. Basic pH sensor and graphs for reference and measuring electrode.

pH Measurement

pH measurement system is composed of pH measuring electrode, a reference electrode, and a high input meter[21]. H^+ sensitive glass bulbs can be used as pH measuring electrode, on the other hand reference electrode is not sensitive to hydrogen ion. The sample is placed in the cup and measuring electrode is kept inside that where as reference electrode is kept in a medium with fixed pH. The difference between voltages of two electrodes is measured with the help of voltmeter and that voltage difference is then transferred into pH.

IV. WEARABLE DESIGN OF HELMET

There are many oximeter designs available but only some of them have been tested in real time environment. And many of them are tested under motion also. More complex tests has been done to compare jaw, chin and forehead locations with the finger based oximeter to determine the best location[6][3].

In wearable computing, design used are different as compare to other computing fields. Here we also need to consider the effects of these components on the body of the worker[7]. Also the design should be of such kind that can be worn throughout the year comfortably by the workers[10]. Body locations on which we can use the oximetery sensor are finger, wrist, earlobe, forehead and facial regions[10].

Table. 2. Comparison between different placement regions[10]

Author	Locations Compared	Motion	Preferred Site
Mendelson *et al* [13]	forehead[R], finger[T]	N	forehead
Mendelson & Pujary [14]	forehead[R], wrist[R]	N	forehead
Narge & Mendelson [5]	forehead[R], finger tip[T], jaw[R], chin[R]	Y	forehead
Nogawa *et al* [15]	forehead[R], chest[R]	N	forehead
Rhee *et al* [16]	fingertip[T], finger[R]	Y	finger

Table.2 gives comparison of results of oximeter sensor placement. Table shows type of sensors compared where [R] denotes reflective and [T] denotes transmissive measurement for motioned and non motioned objects and comparison of measurement sites[10].

Traditionally from very long time we are using finger tips for pulse oximetery measurement even in hospitals we are using the same[11]. Where as in case of wrist, because of its complex bone structure it is not considered to be the best location for light back scattering[8][9]. Finger tip position is not much preferred because it will cover significant part of worker's hand, and it will be difficult for him to do his routine job. In comparison to other locations like earlobe, jaw, chin and forehead, forehead is the best location to which pulse oximetery sensor can be attached. Because in most of the work applications we can easily wear a helmet containing pulse oximetery sensor.

V. PROTOTYPE OF HELMET

The prototype of helmet developed here will be containing two sensors connected to it. First one is pulse oximetery sensor and other one is CO sensor. As shown in Fig.7.

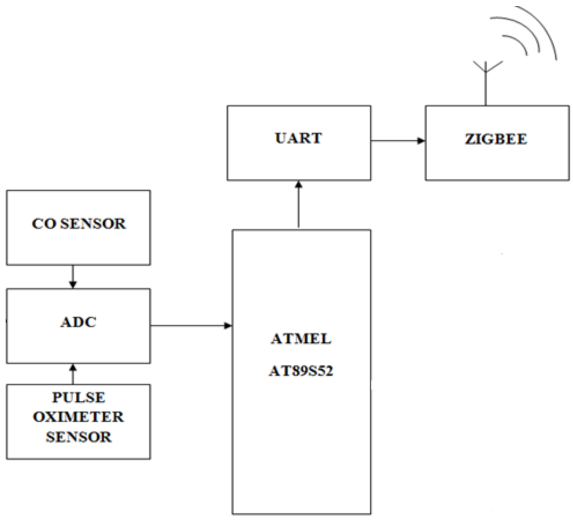


Fig.7 Components of Helmet

Here we are using one more sensor called pH sensor which is not mounted on the helmet but will be

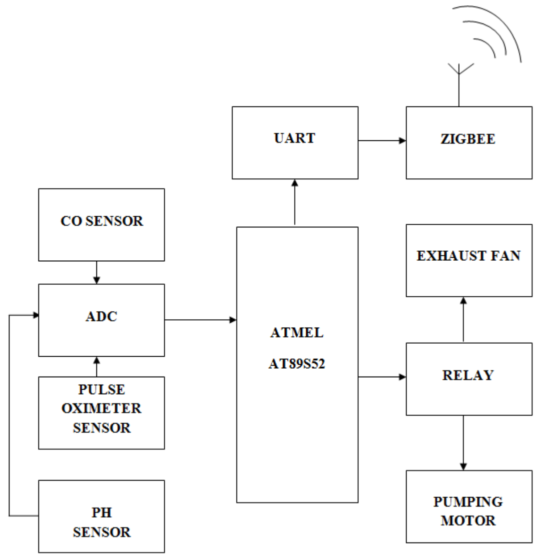


Fig.8 Interfacing of pH sensor, exhaust fan and Pumping to helmet circuitry

interfaced to microcontroller present on the helmet to which other two sensors are interfaced. And this helmet is also interfaced to the exhaust fan and DC motor present in the mine through wires, as shown in fig.8. Here values sensed by three sensors will be received by microcontroller first and then it will be sent to central location through zigbee. Whenever presence of CO is detected inside the mine exhaust fan will be turned on automatically. Similarly when the ore or soil is acidic it will automatically turn on the pumping motor through relay which will spray sodium hydroxide to neutralize that. Zigbee used here is of 2.4GHz. Which is having a data transfer rate of 250kbits/sec.

VI. CENTRAL LOCATION

In this system central location will be like a receiver section, which will be receiving all the parameters which are being transmitted from worker's helmet and will be showing them on the LCD. Central location will also be containing a audio buzzer which will blow whenever the CO level in the mine will be above threshold level. The basic schematic of central location is shown in the fig.9 below.

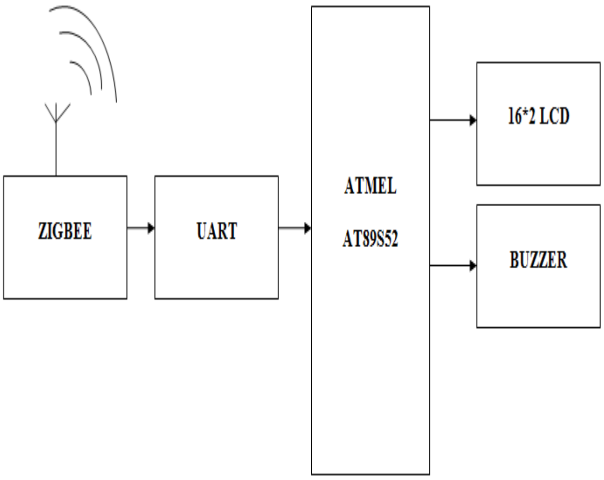


Fig. 9. Schematic of central location(receiver section)

Here LCD will be continuously displaying values of three sensors, here in this LCD we can check the values of heart beat of a particular person and can predict his health condition in advance and can save him by giving him primary treatment well in time. While buzzer will alert all the workers in the mines whenever gas level is higher than particular threshold.

VII. RESULTS

Hence we have implemented the system successfully here along with three sensors which is an improvement over existing system with only pulse oximetery and CO sensor. Here we additionally using pH sensor and components like exhaust fan and DC motor. By continuously checking the health parameters of a person and automatically turning on the exhaust fan on the when CO is detected we have increased the efficiency of existing system.

VIII. CONCLUSION AND FUTURE WORK

Here we have integrated three sensors into to the helmet of a worker by which we can monitor the health conditions of the worker effectively and efficiently. Here we are able to check the health parameters of each worker individually since particular level of CO will effect each person by different amount depending upon the immunity level of that person. Previously the systems available were able to detect the presence of CO only, they were not able to monitor the health parameters of workers. Moreover here we are checking the acidity level as well which can harm the hands of the workers. Thus this protective gear system can increase the safety of workers by significant amount because workers can be warned by the system before getting unconscious or impaired in most of the cases.

Since we have developed a system successfully but still there is much work for us to do. One of the main disadvantage of this system which is to be removed in near future is wired connection of helmet with the pH sensor, exhaust fan and pumping motor. Because this will cause difficulties to the workers from moving from one place to another place. This is only the one side, in near future we can also use this personal protective gear system to reduce injuries due to falls, electrocution, particulate inhalation, and workers on foot being struck by vehicles.

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