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IOT BASED PORTABLE ARTIFICIAL ELECTRONIC OLFACTORY SYSTEM FOR THE SAFETY OF MANUAL SCAVENGERS

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ABSTRACT

In this paper, we intend to produce a safety system for manual scavengers. Unminding "Prohibition of manual scavengers and their rehabilitation act",2013, there are still many private organizations across the Indian states, hire labourers for incredibly low cost of around 1.5k whereas cleaning process abiding law and using equipment's like suction tanks, cleaning robots, sewer lorries would cost around 5k for the same task. The ultimate reason for such violation of act is the monetary factor on both sides. When such manual scavengers are exposed to gases like methane, ammonia, hydrogen disulphide etc., which are present inside the manhole, drainage or sewage system, they encounter many health troubles. Few of them include breathlessness, fatigue, bacterial and viral invasion, infections, loss of consciousness and ultimately death in worst case. During such times, the labourers will not be in line of sight and as all happens in sudden, the victim cannot intimate the supervisors above and as a result, they go unconscious. If not rescued within time, the victim dies. In order to prevent this from happening, we propose a safety system that continuously monitors the toxic gas levels, heart rate of the subject and the respiratory rate. If anything abnormal is detected, the system immediately triggers buzzer, an alert message that can be seen by the supervisor above using IoT. This in turn helps rescue faster, so that the victim can be hospitalized before the vitals goes extremely down. The application of the system is flexible so that it can be used in detection of other gases by modulating the program accordingly and setting the required threshold.

Keywords: alert, electronic olfaction, manual scavengers, microcontroller, threshold, toxic gas level.

1. INTRODUCTION

In past few decades, electronic sensing or e-sensing technologies have undergone undoubtedly important developments from a technical, commercial and systemic point of view. This refers to the capability of reproducing human senses using sensor arrays, machine learning and pattern recognition systems. The research has been conducted to develop technologies, commonly referred to as electronic noses that could detect and recognize odours and flavours, since 1984. The stages and steps involved in the recognition process are similar to natural human olfaction which are performed for quantification, identification, comparison and other applications, including data storage and data retrieval. These devices have undergone much development, advancements and reliability to fulfil industrial needs. But the miserable part is that the drainage workers who enforce themselves in a risky environment are not provided with any safety device [1]. Therefore, we propose a safety system for such workers, who risk their life for meagre pay.

2. GENERAL DESCRIPTION

A. Electronic Olfaction and Natural Olfaction

Naturally, there are around 400 types of scent receptors with the ability to detect at least 1 trillion unique odours. Initially the odour particles bind to the olfactory receptors and the signal is carried all the way to the central nervous system. The neural system compares the odour with many pre recognized types and identifies. Whereas in electronic olfactory system, the data from the sensors are processed after digitizing. The processed signal is then passed to advanced neural network techniques and compared with the samples to predict the type of odour as shown in Figure-1. Though there is a noticeable gap in accuracy, electronic olfactory system is still reliable in cases where natural olfaction fails.

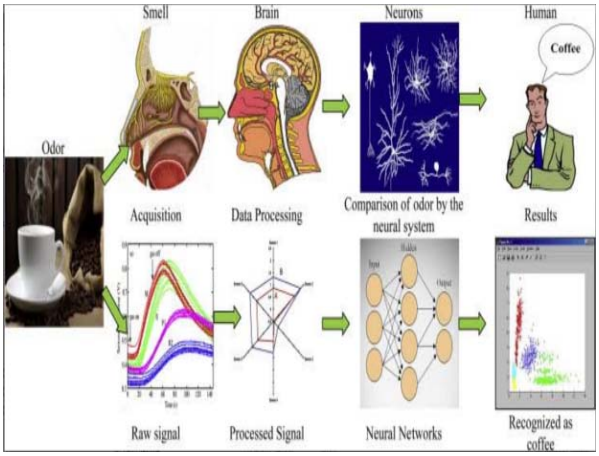

Figure-1. Natural and electronic olfaction system model.

B. Manual Scavenging

Manual Scavenging is the term used in indication of involving humans in the process of cleaning, carrying or disposing wastes or human excreta. An estimated 1.2 million scavengers in the country are involved in the sanitation of our environment and surroundings. The working conditions of these sanitary workers have remained virtually unchanged for over a century. Apart from the social atrocities and insults that these workers face, they are exposed to various health problems by virtue of their occupation [2]. These health troubles and hazards

include exposure to harmful gases such as methane (CH_4) and hydrogen sulphide (H_2S), cardiovascular degeneration, musculoskeletal disorders like osteoarthritic changes and inter-vertebral disc herniation, leptospirosis and helicobacter, skin problems, infections like hepatitis, respiratory system problems and altered pulmonary function parameters. This can be prevented through legislative, engineering and medical measures [3]. While the engineering measures help in protecting against exposures, the medical measures help in early detection of the effects of these exposures. This can be partly achieved by developing an effective and suited occupational health service for this group of workers [4]. Including these, regular awareness programs should be conducted to impart education regarding safer work procedures and use of personal protective devices [5].

C. Health and Life Hazards of Manual Scavenging

The effect on health is directly proportional to the exposure level. Few toxic gases that manual scavengers are exposed to are hydrogen disulphide, methane, carbon monoxide and ammonia. There are few other toxic gases too but in a little amount and hence those gases have least impact on health. A study shows that 26 sewage workers were exposed to such environment and found that around 53.8% developed sub-acute symptoms like chest tightness, sore throat, cough, breathlessness, irritability and loss of libido. The severity worsened in proportional to the rate of exposure [6]. Another study exposed 68 sewage workers to hydrogen disulphide and found that FVC values are far lower than normal ones [7]. If inhaled in massive amounts; it rapidly produces anoxia and results in death by asphyxia. Sub-acute poisoning due to such gases leads to bulbular conjuctivities, palpebral edema, mucopurulent secretion and in turn reduction in visual acuity commonly known as “gas eye” in sewage workers terms. Long term exposure ultimately results in mortality or severe bacterial or viral invasion. According to “Prohibition of employment as manual scavengers and their rehabilitation act” in 2013, involving manpower in physically disposing excreta and other toxic wastes are considered crime and violation of law based on human rights. But there are still many private organisations that hire manual scavengers for such work in order to reduce cost of cleaning and disposal.

D. Death Toll

From 1993 till 2019, 814 deaths of manual scavengers have been recorded as shown in Figure-2. This is just the recorded count. Actual death count is far more than the recorded count and near-death damages are not considered into account, if included the numbers would cross ten thousand as shown in Figure-3. Apart from the governmental departments, many private organizations also engage manual scavengers to clean septic tanks and sewers. Referring to the fact that most deaths occur in private apartment complexes or establishments and when it comes to choosing between a suction pump in a lorry or human beings, employers tend to choose the latter since they are much cheaper. A septic tank cleaning lorry charges Rs 5,000 roughly for cleaning, whereas the same job when done by human beings costs much less. So, employers see cost factor and fail to abide with the law.

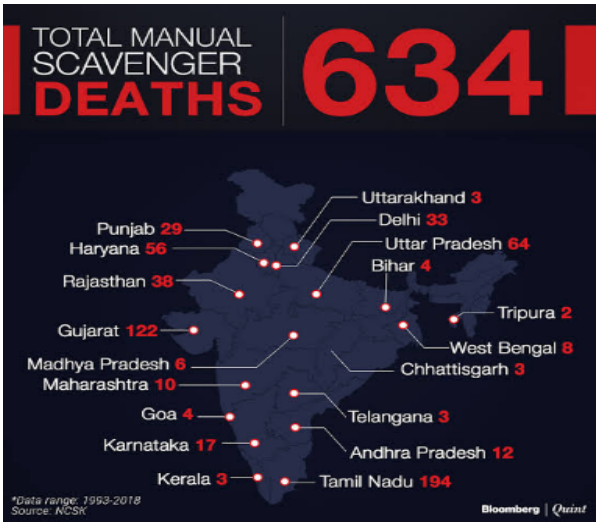

Figure-2. Death toll.

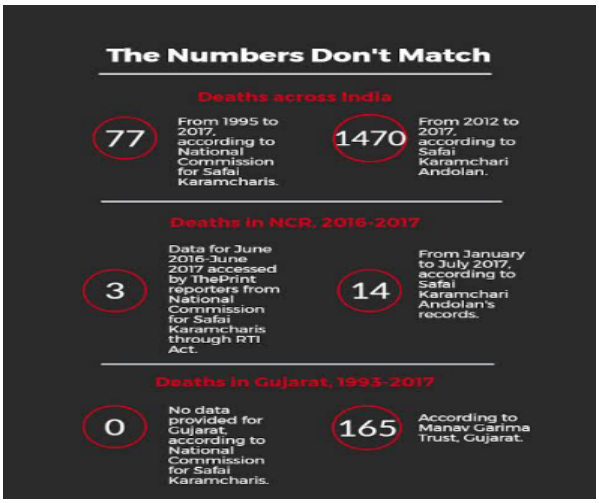

Figure-3. Proof that all manual scavenging deaths are not recorded.

3. EXISTING SYSTEM

Manual monitoring and cleaning become necessary when there is unexpected increment in the underground waste water level, blockages or leakage issues where using advanced cleaning techniques and usage of machineries become difficult. Few recent technologies using IoT and two way communication eases conveying information in a better way [8-10], techniques using classification, detection and comparison methods for identification of specific gases helps in analysis of various gas components with the help of few basic electronic nose skeleton [11-15], composite feature extraction based on covariance matrix and gas chromatography methods aids the findings [16-18], Swipe card model, Convolutional Neural Networks (CNN) based and Multilayer Perceptron Neural Network (MPNN) based techniques further can

enhance the efficiency and accuracy [19-22]. There are many such studies trying to ensure the safety of sewage workers but in different aspects. Few of them include using the GSM module as a messaging system. This paper is based on selectively analysing similar papers and improvised the functionality as a single system for serving its single purpose [23-30].

4. PROPOSED SYSTEM

This paper proposes a safety device connected to the internet using IoT protocol as shown in Figure-4. This updates all vital signs of the subject in the webpage continuously on timely basis. Death mainly occurs due to excessive inhalation of toxic gases like methane, ammonia, carbon monoxide etc., released as the result of chemical reaction between molecules and the microorganisms present. First, the subject has trouble in breathing due to the suffocation and if that prolongs, it leads to unconsciousness. As the subject become unconscious, risk signal can't be manually given to the supervisors. If unrescued within certain time, the subject tends to die. The ultimate reason is the inability to communicate which is solved in our proposed system as we continuously monitor respiration and pulse of the subject along with the detection of toxic gases. Once the concentration of such gases increases the fixed threshold, the situation becomes unsafe for the subject and alert signal is activated. The flow of how the system works is shown as a flow diagram Figure-5. The ultimate purpose of driver circuit in this system is to drive the pump motor which requires higher voltage supply compared to other components present in the system. The input 5V DC is amplified to approximately 12 V to meet the requirement.

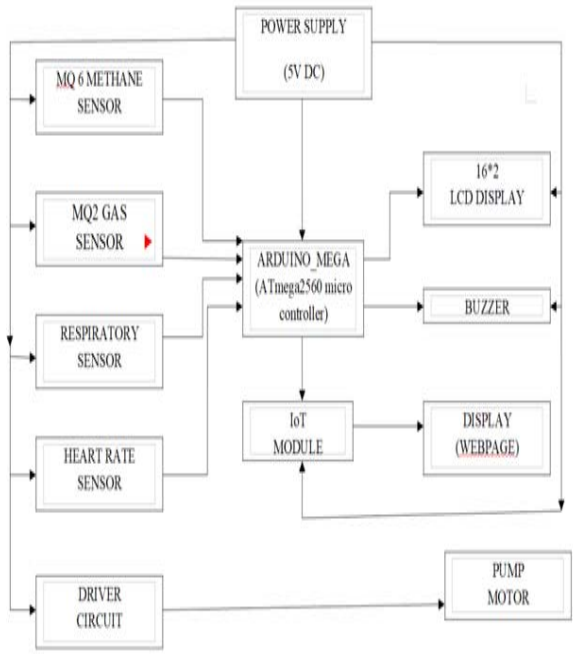

Figure-4. Implemented block diagram.

A. Hardware Description

Arduino mega: Mega2560-CORE is a small, complete and breadboard-friendly board based on the ATMega2560. Its design is based on the Arduino Mega2560, so we can use it as an Arduino Mega2560 development board. The operating voltage is 5V where the input recommended voltage is 7-12V. It has 54 digital I/O pins of which 14 provide Pulse Width Modulation (PWM) output and there are 16 analog pins.

Driver circuit: The ULN2003 is a monolithic high voltage and high current Darlington transistor arrays. It consists of seven NPN Darlington pairs that feature high-voltage outputs with common-cathode clamp diode for switching inductive loads. The collector-current rating of a single Darlington pair is 500mA. The Darlington pairs may be paralleled for higher current capability.5V input is sufficient and has the ability of amplifying the output voltage upto 50V.

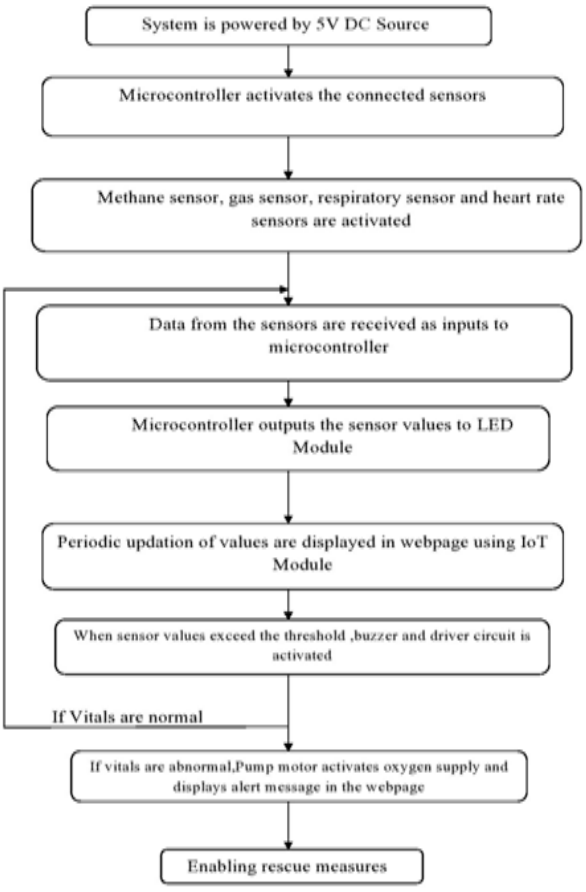

Figure-5. Flow diagram.

Respiratory and Heart rate sensor: The input voltages of both are 5V DC and both provide instant digital output that is directly connected to the microcontroller.

MQ_2 and MQ_6 Gas Sensors: The threshold values are 550 and 600 in range 0-1023.These threshold values are detected based on the reading shown when subjected to test. These sensors give analog input to the microcontroller.

B. Software Description

Embedded C: High level languages are used in implementation of circuits using arduino, raspberry pi etc. Here Embedded C serves its purpose for it is designed to bridge the performance mismatch between Standard C and the embedded hardware and application architecture.

Arduino IDE: This is development platform for programming using ranges of arduino kit as it is compatible to large range of microcontrollers.

5. IMPLEMENTATION

The proposed system has been implemented using Arduino mega board using ATmega 2560 microcontroller. The output of Respiratory sensor, heart rate monitoring sensor, gas sensors like MQ_2 and MQ_6 are connected to the input pins of Arduino and the output pins from Arduino is given to IoT module, Driver circuit, buzzer and LCD. All these hardware runs on a 5V DC source which is powered by the power supply as shown in Figure-6. As the minimum voltage required for a pump motor is 12V, it is provided by the driver circuit.

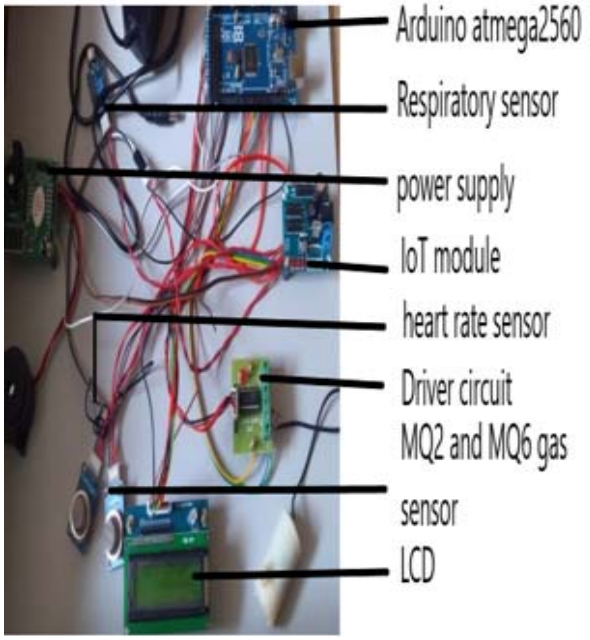

Figure-6. Implemented circuit.

6. WORKING

Once Arduino is powered up, the data from all connected sensors are monitored based on the fixed threshold. Respiratory sensor function is time based input, if the subject doesn't breathe for around 25 plus seconds, trigger pulse is sent to microcontroller. Heart rate sensor continuously monitors the rate of the subject and the gas sensors with threshold fixed to 500 and 600 where the entire range of the gas sensors are 0-1023. Other gases can also be detected by identification of the density and setting the identified value as the threshold. Any abnormalities in the inputs of the sensors triggers pulse and in turn activates alert message by powering up the buzzer and LCD. The data throughout the time will be updated using IoT module and any abnormalities can be supervised by the supervisor so that rescue becomes easy. Once breathing becomes difficult, the pump motor is activated and further including portable oxygen cylinders can suffice breathing by automatically triggering, therefore maximizing the chances of survival.

The following screenshot of the IoT webpage displays the density value detected in the gas sensor as first column. The second column holds the reading of methane sensor. The third column indicates the state of respiratory sensor and the subsequent column indicates the condition of the subject's heart rate using heart rate sensor. The webpage also displays the corresponding date and time by which the reading is taken (Figure-7). When the first two columns reading fall below 550 and 600 respectively, gas level is alarming and the next two columns directly indicate normal and abnormal conditions.

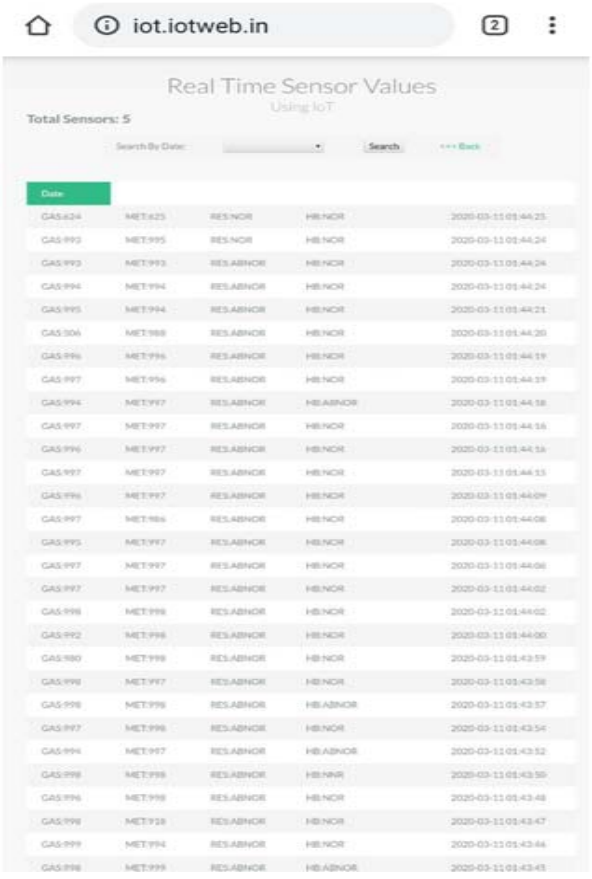

Figure-7. Output.

7. CONCLUSIONS

This paper focuses on the safety of manual scavengers by intimation of alert signal to the supervisors or the respective in charge, using IoT. We witness much technological advancements over the decade, and there are modern equipment's to serve the purpose. Inspite of having safe and advanced disposal methods there are still lot of manual scavengers losing their lives and the number of such deaths recorded is very less than the actual number of occurred deaths. As a future scope, this proposal can be extended to various applications like mining, chemical industries, other factories etc., by extending the code and fixing different threshold values. Currently this system helps in minimizing the overall death count by alerting, if any trouble is encountered based on the cumulative inputs of sensors. As an extension, portable oxygen cylinders can be fixed to facilitate breathing by automatic triggering when needed and based on the health condition, message could also be sent to the nearest hospital to accelerate rescue rate.

FUTURE SCOPE

There are indeed advanced techniques using machine learning and artificial intelligence. This work can further be improved by alerting the nearby hospital based on the subject's vitals and the proposed work can have an additional feature providing oxygen supply when needed to the subject by letting the subject carry the portable oxygen cylinder to improve the chances of survival.

Conflict of Interest: The authors find no conflict of interest.

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