An IoT Based Proposed System for Monitoring Manhole in Context of Bangladesh

Saadnoor Salehin[1], Syeda Sabrina Akter[2], Anika Ibnat[3], Tasmiah Tamzid Anannya[4], Nurun
Nahar Liya[5], Manisha Paramita[6] and Md Mahboob Karim[7]
Department of CSE, Military Institute of Science and Technology, Dhaka, Bangladesh
saadnoors9@gmail.com[1], sabrina.akter1106@gmail.com[2], anikaibnat87@gmail.com[3],
liyanurunnahar@gmail.com[5], manishaparamita1996@gmail.com[6] and mahboob4146@yahoo.com[7]

Abstract— In developing countries, manholes are not monitored properly. These unsupervised manholes can prove themselves to be a threat to lives in various ways. This paper presents an intelligent automatic manhole monitoring system which detects harmful chemicals and toxic gases inside the manhole, absence of the lid of the manhole and generates an alarm to the passersby in that situation, alerts the authority about the system state. The system can improve overall quality of the surroundings. Hence, the concerned authorities can take proper measures to maintain the manhole. The system has been implemented in an academic environment to carry out the automated monitoring of a manhole to evaluate the proposed features.

Keywords—Manhole, Sensors, Interfacing, Garbage Overflow Detection, Manhole Monitoring, Motion Detection, Internet of Things

I. INTRODUCTION

Manhole which is meant to carry out inspection, cleaning and removing obstruction in the sewer line is also becoming the reason of accidents, taking lives and affecting them. Most of the systems in the developing countries are not automated. Most of the cities is currently using a poor underground drainage system and it is the duty of managing station to maintain cleanliness of the cities. If the drainage maintenance is not thorough, the pure water gets contaminated with drainage water and infectious diseases may get spread. The drainage gets blocked during rainy season, it might overflow and create problem for routine life such as traffic may get jammed, the environment becomes dirty, and consequently public become upset.

Usually, manholes are covered with metal lids that keep it safe for passersby. If the lid is not closed properly, then there is a chance of accidents and also people may get fall into the drainage. Often during dark, people may not notice an open manhole which increases the number of accidents. There are several accident occurred in the past all over the world because of falling into the manholes. In 2016, a sanitary sewer cleaner was found dead after falling in a manhole [1] in Humble, a city in Texas, USA. Another accident happened in Bengaluru, India, where four motorists fell due to damaged manhole cover in July 2017 [2]. In 2017, teenage girl died after falling into an open manhole in Gazipur, Bangladesh [3]. In Bangladesh, it is reported that there are many open and unprotected manholes

in the capital city and many accident occurrences has come to light.

The manhole cleaning process is a big issue. The article here [4] depicts that manhole gas mixture found in the sewerage pipes is mainly containing toxic gases like, Carbon Monoxide(CO), Hydrogen Sulphide(H_2S), Methane(CH_4), Ammonia(NH_3), Carbon Dioxide(CO_2), Nitrogen Oxides, etc. Exposure to these gases may cause threats to human lives. Usually to clean the sewerage, a cleaner has to go down through the manhole and the presence of the toxic gases leads to serious health issues including Carbon Monoxide poisoning that causes death.

Explosions in sewer have been occurred in almost every large cities. In 1916, an explosion occurred in a gate valve manhole in Montreal [5], in which two men were injured which was caused by an illuminated lantern that ignited the gases of manhole. Such explosions are usually followed by high rise in the temperature and pressure inside the manhole which can lead to smoke explosion.

Giving less emphasis on monitoring manholes all over the country causes greater problems than it is realized. Automated manhole monitoring system lessens these problem stated above to some greater extent.

The automated manhole monitoring system proposed in this paper will help the officials of Municipal Corporation by informing them immediately after garbage overflow and the exact location where the sewerage or manhole needs to be cleaned up. If at any time, the cover of the manhole gets lost or stolen, then the authority will be notified immediately by using the system. By using a motion detection system, human presence near an open manhole can be recognized and the system can warn people by triggering an alarm system. Thus, the manholes can be kept secured. The system will detect presence of poisonous gases and let the cleaners know the current state of the manhole environment by using an LED indicator. It will also monitor the fluctuation of temperature and pressure inside the manhole. The presented system in this paper creates an user friendly environment to make life easy for every person walking on streets as well as people related to the maintenance of manholes, i.e. municipal officials, sweepers, cleaners etc.

The organization of the rest of the paper is as follows. The previous work related to manhole monitoring system is presented in Section II, Section III represents the overall exper-

imental environment of the system and the system architecture. Section IV discusses the implemented system, the results of the experiment done. Finally, Section V concludes the paper with a discussion about any difficulty that may be faced while implementing the whole idea in the system structure or the process that can be followed to ease the task.

II. Literature Review

Previously, monitoring manhole was not a matter of concern until it caused severe damages to the people of the neighbourhood. There have been many researches on manhole monitoring devices and methods. The first step towards securing the cover was invention of a temporary cover made of glass fiber. In this paper, [6], the author mentioned a method of protecting a manhole opening through a ground surface, the opening covered by a permanent cover that fits into the opening and rests on a ledge extending inwardly from an outer edge of the opening.

The research [7] presented a monitoring system for detecting high liquid levels in a waste water handling system. Wireless sensor modules, network and a processor system were parts of it.

In the meantime, there was another research, [8] which summarizes the design of passive automatic flushing systems installed in the City of Cambridges storm and sanitary sewer system.

In 2007, an author represented a method to secure manhole access-ways here [9]. This invention generally relates to mechanisms for preventing unauthorized access into manhole access ways. It includes locking pins that can be used and insert inside and outside security equipment or components, holes that allow gas ventilation, a security cover under existing manhole metal cover, devices are of many categories to measure different materials related to gas, water elements and garbage etc.

Another new research [10] relates to a resilient pad that is attachable to a manhole cover. The cover is designed to support surface loads, and the frame transmits those loads to the underground supporting structure. It has been recognized that it is advantageous to develop a system for raising manhole elevations that is simple and inexpensive and which also makes manhole covers more useful.

The latest research in this regard, [11], represents the implementation and design function of an Underground Drainage and Manhole Monitoring System (UDMS) for IoT applications. The vital considerations of this design are low cost, low maintenance, fast deployment, high number of sensors, long life-time and high quality of service. The model proposed here discusses about a system of monitoring the water level, atmospheric temperature as well as the pressure inside a manhole checking whether a manhole lid is open.

In summary, we find that some of the studies only highlighted on securing the lid, whereas some focused on an innovative cleaning system inside the manhole. Still those were inefficient, unfeasible and expensive in context of Bangladesh. Other studies discussed about the prevention of unauthorized entry attained through manhole access ways. This study will approach to fill in those research gaps by offering an intelligent system which will monitor all the required data of a manhole and also notify the concerned authority in a cost effective and efficient way.

III. Conceptual Design of the System

The automated manhole monitoring system helps with peoples' anxiety while walking on the streets as accidents may occur because of the absence of the lid as well as it helps the accountable authority. The goal of this system is to establish an automated system to reduce accidents caused by the stealing of manhole covers by detecting lethal gasses inside the manholes, notifying the authority if a manhole is in danger of overflow and others. The system is intended mainly for the safety of the passersby and sweepers who work in the sewerage cleaning team. The proposed system will also help the proper authority of the city to monitor the conditions of all manholes remotely.

The concerned authority to control the system and receive data or notification varies from countries to countries. For example, Bangladesh is subdivided into more than 200 municipalities [12]. Outside of Dhaka, Chittagong and Khulna, each municipality is directly responsible for its own water supply, sewerage and storm drainage. Water supply and sanitation in the three largest cities is carried out by semi-autonomous municipal utilities. In the cities of Dhaka, Chittagong and Khulna, the semi-autonomous Dhaka Water Supply and Sewerage Authority (DWASA), the Chittagong Water Supply and Sewerage Authority (CWASA) and the Khulna Water Supply and Sewerage Authority (KWASA) provide water and sanitation.
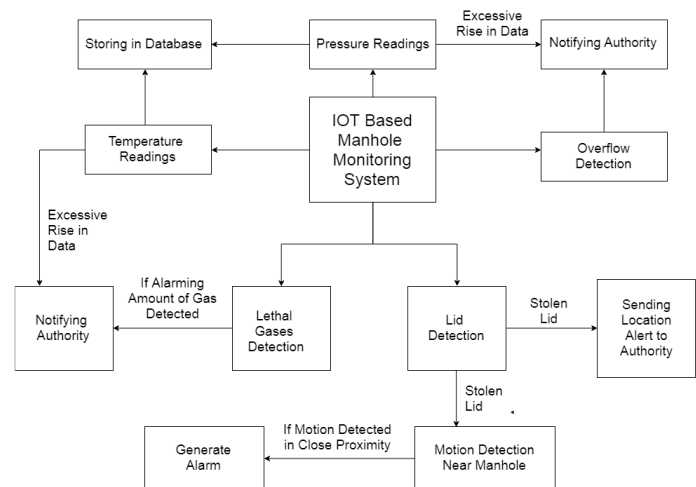

Fig. 1 Block Diagram of The System

The Figure 1 refers to the block diagram of the system. The data of current pressure and temperature of the air inside the manhole are taken by the sensors and stored in the database. If there is a sudden rise in the temperature and pressure due to explosion inside sewerage which is lead by the leakage of natural gasses inside the manhole, then alert message is sent to the authority.

The garbage detection process detects if the level of garbage or water inside the manhole rises up to a certain level. If the garbage height reaches the level, a system notification is sent to the Municipal to alert them about the probable garbage overflow so that cleaning process can be done before its happening.

Different lethal gasses can be present within the manhole, which can be harmful for sweepers who get inside the manhole to clean it. Also, leakage of Natural Gas within the manhole is a regular occurrence. Thus the system checks if the level is more than regular and a light is kept on if it seems harmful to enter the manhole for human.

An open manhole creates problem for the pedestrians. Hence, a method is used to detect the presence of the manhole cover on top of the manhole. In case of thievery, a notification will be sent to the concerned authority about the stolen lid with the location of the open manhole. Again, many a times people don't realize of missing manhole cover and accidents can occur. To prevent this, human presence is checked near the open manhole. Mainly, this is how the entire system is designed to work.

A. Features of the Proposed System

The features of the proposed system are described below:

1) **Cover Stealth Alert:** In Bangladesh, manhole covers thievery has become a very common phenomenon. Too many deaths and tragedies have happened because of missing manhole covers over the recent years in the whole world particularly in Bangladesh. Thus, through the proposed system in this paper proper authorities will be notified whenever the covers are removed from the manhole.

2) **Alarm Generation for Probable Accidental Occurrences:** People strolling within close proximity of an open manhole lead to probable accidental occurrences. Hence, the system will generate an alarm if there are people around an open manhole to make aware of the nearby open manhole.

3) **Presence of Lethal Gasses:** Determination of the presence of lethal gasses in the sewerage is required, as according to the article [4], manhole contains mixture of many poisonous gases such as Hydrogen sulfide (H_2S), Ammonia (NH_3), Methane (CH_4), Carbon Dioxide (CO_2), Nitrogen Oxide (NO_x) and Carbon Monoxide(CO). A very limited time exposure to any of these harmful gases with cleaners and sewerage workers may endanger their lives. The authorities notification process will be adopted in case of massive density of lethal gasses.

4) **Garbage Overflow Alert:** The roads and area near a manhole are affected when garbage overflow occurs. The authorities will be notified when a manhole needs to be cleaned.

5) **Sudden Explosion Alert:** The sudden change in regular environmental data indicates explosion inside sewerage. If there are some drastic changes in temperature, pressure or such other environmental data inside manhole, an alert message will be sent to proper authorities.

6) **Information Stored in Database:** A database will be kept for regular checking of the environmental data such as temperature, pressure, presence of the cover, presence of gasses etc. within the manhole system.

7) **Web Interface:** A web interface will help one to be informed about the current status of a manhole. It will show all the previous and current data related to all the manholes across the city.

IV. System Implementation

A prototype of the system was developed to test the working process of the system in an academic environment. The system includes a sensor circuitry, a processing unit and a database to store data. The sensor circuitry includes all the sensors that are necessary to detect temperature, environmental pressure, garbage overflow and excessive increase of lethal gasses etc. The processing unit processes all the data and takes decision of sending alert to the authority and storing data in the database. The database keeps information about all the variables to keep the authority updated about the current status of the manholes. The total system consisted of two major parts.

1) Database and Web Interface
2) Hardware Implementation

A. Database and Web Interface

All the data from the sensor circuitry are read, processed and stored in the database. Then all the necessary decisions are taken based on the data. The database keeps all the information about all the variables to keep the authority updated about the current status of the manhole. The data is then imported from the database and shown in the implemented sample web interface in real time.

Fig. 2 Sample Picture of Implemented Website

A web interface has also been created to demonstrate how proper authorities can check the status of any manhole at any point of time. The website fetches data from the database and shows it to the user in a simple and understandable manner. Figure 2 is a sample picture of the implemented website of the prototype which depicts the temperature, pressure, lid status and harmful gas in real time.

B. Hardware Implementation

The hardware part includes sensor circuitry and processing unit. Micro controllers were used as processing units. Standard concrete manholes are of 48-inch diameter, minimum depth of four(4) feet and maximum depth of twenty(20) feet [13], measured from the rim to the invert of the manhole. A prototype of this exact size would not have been feasible so the size of the manhole in the prototype was reduced proportionately and the sensors and equipment were placed accordingly. Several test cases were experimented to check the results of the implemented system. To implement the proposed system, it required the following main components.

1) Temperature sensor
2) Barometric pressure sensor
3) Hall effect sensor
4) PIR motion sensor
5) Water sensor
6) Methane gas sensor
7) Carbon Monoxide gas sensor
8) Carbon Dioxide gas sensor
9) Nitrogen Oxide gas sensor
10) Hydrogen Sulfide gas sensor
11) Ammonia gas sensor
12) Alarm / Speaker
13) WiFi module
14) GSM module

Magnetic effect on sensors and metal is used to detect the presence of manhole cover. In this regard, hall effect sensor is used which detects the presence of magnets nearby. The lid which is usually made of cast iron creates magnetic field around the cover and the hall effect sensor detects the field near the manhole when the lid covers it. The absence of cover denotes absence of magnetic field and then the system generates an SMS that regards stolen cover and sends the location of the specific manhole. GSM module is used to send the SMS. The SMS is to be sent to the concerned authorities. Also, the data is passed through wireless medium to the database using WiFi module.

Presence of all the gases inside manhole are detected using individual gas sensors of each gas mentioned above. An LED light is stationed inside the manhole to indicate the presence of these gases. The light goes ON if lethal gases are present to specify the cleaners of the danger of entering the manhole and in the meantime an alert SMS is also sent to the authority. Figure 3 shows an example of the SMS alert which occurs when the presence of harmful gas is detected in our implemented prototype of the system.

To detect the probable overflow of rain water or sewerage water, a water sensor was put inside one quarter height of the manhole. So, when the water reaches the three quarter height of the manhole and the water level touches the height of the sensor then the said system sends an SMS to the authority to clean it up in the previously mentioned manner.

A motion detection system was implemented near the manhole using PIR motion sensor so that people in the close proximity of open manhole can walk safely. The sensor was placed on all sides of the manhole so people coming from any
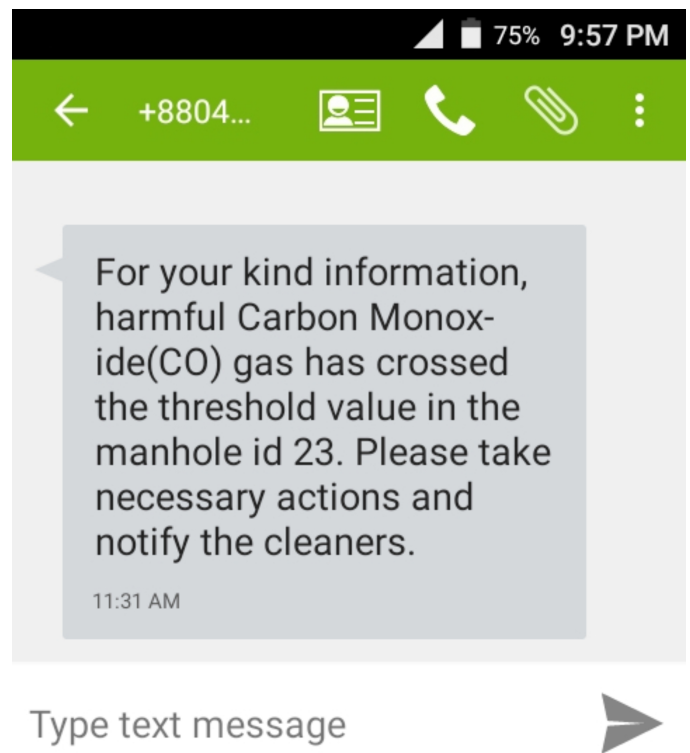

Fig. 3 SMS Notification for Detection of Harmful Gas Inside Manhole

direction can be alerted and a speaker is put nearby to generate the alarm. The sensor is placed in such a distance that alarm is generated well before they come closer to the manhole.

Regular environmental data such as pressure and temperature inside a manhole, the fluctuation of the density of gases, the presence or absence of the manhole cover etc. are detected using barometric pressure sensor, temperature sensor, gas sensors, hall effect sensors respectively and saved in database for further details and the changes in these elements are shown in the web interface. The prototype was implemented using a complete wireless way. All data exchanges were done over WiFi network.

The Figure 4 shows the working procedure of the system. At first, the value of water level, carbon monoxide and hall effect is read. If carbon monoxide is present inside the manhole, the LED light is turned on and notification SMS is also sent to the concerned authority. Otherwise the light remains turned off. Similarly if the water level rises up to a certain level, a notification SMS is sent. The presence of the lid is checked through detecting the magnetic field. If any magnetic field is not detected then SMS is sent and motion sensor starts checking for human movement. If any human movement is detected while no magnetic field is present, the system generates an alarm.
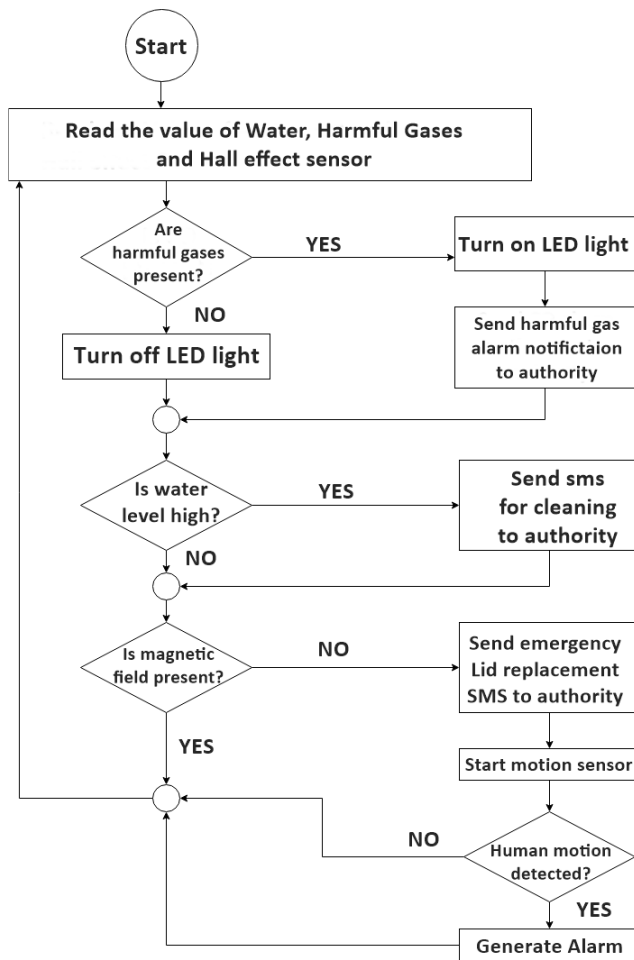
Fig. 4 Working Procedure of the System

Moreover, in developing countries, electricity is a big factor. This system increases demand of electricity. Scalability can be an issue as well if initial budget is low. There are scopes of expanding the features to some extent. One extra feature that can be added is sending text message to nearby travelers of the open manhole. They can be travelling in any vehicle or just can be walking.

REFERENCES

[1] "Man dead after falling down manhole in humble," Available: http://abc13.com/news/man-dead-after-falling-down-manhole-in-humble/1232637/, Mar. 16 2016, [Online; accessed 25-May-2018].

[2] "Damaged manhole causes four motorists to fall," Available: http://www.thehindu.com/news/cities/bangalore/damaged-manhole-causes-four-motorists-to-fall/article19329589.ece, 22 2017, [Online; accessed 25-May-2018].

[3] "Gazipur girl dies falling into manhole," Available: http://www.theindependentbd.com/arcprint/details/84914/2017-03-12, Mar. 12 2017, [Online; accessed 27-May-2018].

[4] V. K. Ojha, P. Dutta, H. Saha, and S. Ghosh, "Detection of proportion of different gas components present in manhole gas mixture using back-propagation neural network," *International proceedings of computer science and information technology*, vol. 1, pp. 11–15, 2012.

[5] F. V. DOWD, "Explosions in sewers," *Canadian Public Health Journal*, vol. 26, no. 9, pp. 440–446, 1935.

[6] T. Walsh, "Temporary manhole cover and method," Jun. 25 1996, uS Patent 5,529,431.

[7] J. Pasko, "Manhole cover liquid level monitoring system," Jul. 11 2003, uS Patent App. 10/618,216.

[8] W. C. Pisano, O. C. ORiordan, F. J. Ayotte, J. R. Barsanti, and D. L. Carr, "Automated sewer and drainage flushing systems in cambridge, massachusetts," *Journal of Hydraulic Engineering*, vol. 129, no. 4, pp. 260–266, 2003.

[9] G. K. Dennis, "Apparatus and method to secure manhole accessways," Apr. 10 2007, uS Patent 7,201,534.

[10] J. Kelley and D. Elder, "Manhole cover device," Feb. 21 2012, uS Patent 8,118,517.

[11] S. Muragesh and S. Rao, "Automated internet of things for underground drainage and manhole monitoring system for metropolitan cities," *International Journal of Information & Computation Technology. ISSN*, pp. 0974–2239.

[12] Wikipedia, "Water supply and sanitation in bangladesh," Available: https://en.wikipedia.org/wiki/Water_supply_and_sanitation_in_Bangladesh, 2012, [Online; accessed 11-May-2018].

[13] "Sewer design guidelines," Available: https://www.wsscwater.com/files/live/sites/wssc/files/Design%20Manuals/S-18-2008_19826.pdf, [Online; accessed 11-May-2018].

V. DISCUSSION AND CONCLUSION

The Automated Manhole Monitoring system if implemented properly can bring revolutionary changes in the environment as well as in the day-to-day life of people. The proposed system ensures securing the human lives of the passersby through prevention of accidents which has become a common occurrence nowadays in Bangladesh and also other developing Countries. It prevents thievery, considers safety of the sweepers and makes cleaning process easier by predicting unnecessary water and garbage overflow. While testing all the features, a standard delay of 3 seconds in updating the database was recorded. The reason behind this delay is that some sensor tends to create delays in operation and the WiFi module that is used in this particular system needs 500 milliseconds to execute a data exchange command. However, the delay is very less comparing with day-to-day life. Again, all sensors and equipment need to be water and dust proof so that they can sustain inside a manhole. The main drawback of not using water and dust proof sensors are that they can easily get destroyed. Therefore, maintainability is a matter of concern.