Internet-based monitoring and warning system of methane gas generated in garbage center

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Abstract. This paper introduces a system which can monitor the environment of the garbage center in a city. Comparing with developed countries, they have technologies to process garbage, while those technologies are still difficult to be implemented in developing countries. In Indonesia, garbage are mostly placed in a wide-open area called landfill, where methane gas could be produced by a decomposition process. The gas has a characteristic that it can be burned easily. However, it is potentially to be used as an alternative energy for gas stoves. Considering this characteristic, the gas should be managed appropriately for both of distributing and monitoring gas leakage. Since the production of methane gas is plentiful enough, the gas can be distributed among the households surrounding the garbage center. Monitoring of methane gas has to be done continuously and real time during producing and distributing, without generating pollutions to the environment. Here, the monitoring system has been developed using a micro controller equipped with a methane gas sensor, i.e., TGS 2611. The data of monitoring will be distributed using an Internet-based system, where a Wi-Fi module is attached to the micro controller to send and communicate with the web-based server. Furthermore, information of monitoring the gas can be accessed by using android application. The advantage of the proposed system is that the user can monitor, record, and get the information of gas level. The system can also be used as an early-warning system when the gas exceeds the limit and when a danger situation occurs. The proposed system was tested using the black box method to evaluate the functionality. Finally, the system is used to optimize the Waste Management program through the utilization of methane gas. Hence, the utilization of methane gas monitoring system is tested to the user, whether they can use it easily.

1. Introduction
Garbage could be the most problem of cities in Indonesia. Quantity of municipal solid waste (MSW) has been increasing year by year. Ministry of Environment and Forestry (LHK) reported that garbage tonnage in Indonesia could be 64 million tons per year in 2017 [1]. In order to reduce the capacity, there are some strategies used, such as landfill, combustion, recycling, recovery, reducing and composting. Comparing with developed countries, where they have those technologies to process

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garbage, those technologies are still difficult to be implemented in developing countries. In Indonesia, there are some problems need to be addressed, such as high MSW generation, low quality waste management, limited final disposal sites, and financial [2]. According to the Central Bureau of Statistics, 84.51% of MSW in Indonesia was disposed without shorting process [3]. Furthermore, the garbage are collected at the garbage center, which are mostly placed in a wide open area called waste landfill. From some research results, there are some advantages and disadvantages of surrounding waste landfill. An organic carbon in the waste landfill produces methane gas (CH4) and carbon dioxide(CO2) decomposed by microorganism. Waste landfills have been known as one of major sources of greenhouse gas (GHG) and as the responsible for 20% increasing global warming [4,5]. Furthermore, These waste landfill sites could be major source of land, air, ground and surface water pollutions and very harmful for communities who reside surround landfill sites. Improving the awareness of communities is the most important thing to reduce the impact of waste disposal pollutions. Management of landfill waste site is an important parameter to be implemented as a practical model to resolve the problems regarding pollution and hazardous health problems. Here, introducing control and routine preventive measures should be used for reducing the levels of various kinds of infections [6].

Reducing the negative effect of producing gas at waste landfill could be important part to reduce a potential conflict with communities surrounding the garbage center. CH4 is one of major GHG sources. However, it has a potential to be used for alternating energy for gas stove or also electricity. However, these applications require information about composition and quantity of biogas produced [7]. The aim of this paper is to describe the developed system, which can help communities to monitor, record, and get the information of gas level surrounding garbage center. Since CH4 production is not homogeneous, various representative gas monitoring sites is necessary to be developed [8]. Here, the monitoring system has been developed using a micro controller equipped with a methane gas sensor, i.e., TGS 2611. Thus, monitoring systems can provide the gas level to determine the action needed to control or decide actions considering situations at landfills and disposal sites [9]. The system can also be used as an early-warning system when the gas exceeds the limit and when a danger situation occurs. Methane concentration measurement results are evaluated according to the limit values. If the measurement results exceed the limit values, warning message is sent to the officers. While the previous work monitoring system is developed as web-based computer application [10], this research develops a monitoring system which can work using Wi-Fi communication. The data of monitoring will be distributed using an internet-based system, where a Wi-Fi module is attached to the micro controller to send and communicate with the web-based server. Furthermore, information of monitoring the gas can be accessed by using android application.

At the rest, this paper is organized as follows. Section 2 presents the situation of waste landfill, which is observed the potential CH4 produced at the landfill sites. In Section 3 describes the proposed system of CH4 monitoring system. Section 4 discusses the observation of CH4 monitoring result. The last, Section 5 present the conclusion.

2. Waste Landfill Situations
One of the biggest garbage center at East Java is the Klotok’s landfill, which was established in 1992, and it has been already 25 years old. The area of this landfill is about 2.5 ha, which is used to collect garbage surrounding Kediri city with the capacity until to 576.35 m3. Here, the garbages are collected at the open area at around 1 ha, with the height is designed up to 10 meters for each zone. Figure 1 shows Klotok’s landfill area from satellite. The landfill is devided into two areas, i.e., old area, which is marked with red color, while the newer area is marked with green color. The newer area has been already 3 years old (called as active zone), while the older area of waste landfill has been 25 years old (called as inactive zone).

In this research, the observation was done using sampling method, i.e., 3 area sampling, which are selected from Klotok’s landfill performed on 1.5 meter and 3 meter depth below the surface of landfill. This gas was monitored using pipes as shown in figure 2. The material of pipes use the high density
landfill polyethylene (HDPE) with 4 inch of diameter. Here, CH4 flows through the pipes, which are connected to the developed CH4 Monitoring System. Then, the system will monitor, record and give the information of gas level.

Figure 1. The Picture of Klotok’s Landfill

Figure 2. The picture of Pipe’s Installation

3. CH4 Monitoring System
The CH4 Gas Monitoring Systems should be planned, designed and applied appropriately for monitoring and controlling gas at the waste landfill [11]. In order to develop CH4 Monitoring System, the developing system was done using System Development Life Cycle (SLDC) [9]. The developed CH4 monitoring system is designed to have abilities to monitor, record and give the information about CH4 gas level. Here, the developed system can also be used as an early warning system, which sends alert when the CH4 gas exceed the limit. The users can monitor the gas level using web-based computer application and android application. Figure 3 shows the developed monitoring system. The system consists of CH4 gas sensor, unit processing, wireless module data communication, unit display, buzzer, data storage, and data base.

Figure 3. The Proposed of CH4 Monitoring System

Here, the developed system is equipped with WIFI module to be used for data communication, which is connected to the serial communication on digital pins of unit processing, so the system sends the data to the data base system via WIFI connection. The developed system reads the level of CH4 using TGS2611, CH4 gas sensor. Before CH4 gas sensor is used, it should be calibrated so system can send the data precisely [12]. The data is recorded to the storage unit and sent to the database system. Network server updates web based service for users, which can access using computer application or Android application. If the measurement of CH4 level exceeds the limit values, a warning alert is sent to the officers using buzzer, and network server sends a warning notification to users via the computer or android applications. The block diagram of detailed proposed system is shown in figure 4.
Here, the web-based computer and Android applications have some functions, i.e., (1) show the data as readable graph by real time; (2) report the data as document; and (3) give the notification if CH4 level exceeds the limit. The developed system works as the flowchart shown in figure 5 while the figure 6 will shown the flowchart of monitoring system at the network server.

![Block Diagram of CH4 Monitoring System](Image)

**Figure 4.** Block Diagram of CH4 Monitoring System

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![The Flowchart of CH4 Monitoring Device](Image)

**Figure 5.** The Flowchart of CH4 Monitoring Device

![The Flowchart of monitoring system at the network server](Image)

**Figure 6.** The Flowchart of monitoring system at the network server

![Data base of CH4 Monitoring System](Image)

**Figure 7.** Data base of CH4 Monitoring System

The database system has important role on developing this system. Here, the database consists of tbl_user, tbl_methane, tbl_alert. The tbl_user is used to build a login system for the application. The
tbl_monitor is used to save the maximum and minimum values of CH4 gas every day, while tbl_methane is used to save all records of CH4 values as real time. The tbl_alert is used to save data when the measurement results exceed the limit values. These tables are connected user Entity Relationship (ER) diagram as shown in figure 7.

4. Experiment Result
The experiment is done to measure CH4 Gas of the newer landfill area compared with the older area. Each landfill devide into three terrace with 3 point area of measurement, where the gas level is compared based on depth of each pipes and time of sampling. Here, two kind of pipes are used, i.e., 1.5 meter and 3.0 meter. Table 1 shows the data comparison considering the depth of each pipes in older waste landfill.

Table 1. Data comparison based on depth of each pipes in older waste landfill

| Depth | Pipe 1 (% Vol) | Pipe 2 (% Vol) | Pipe 3 (% Vol) |
|-------|---------------|---------------|---------------|
|       | 1.5 meter     | 3 meter       | 1.5 meter     | 3 meter       | 1.5 meter     | 3 meter       |
| Day   | M  E  M  E   | M  E          | M  E          | M  E          | M  E          | M  E          |
| 1     | 0   2.86 2.78 | 59.91 59.10 52.88 61.72 | 0   0 1.04 0.78 |
| 2     | 0   4.95 8.06 | 63.59 61.92 59.88 65.60 | 0   0 4.03 4.84 |
| 3     | 0   2.84 4.03 | 64.19 66.34 66.10 65.58 | 0   0 1.10 3.28 |
| 4     | 0   2.57 2.22 | 66.47 61.18 60.10 61.62 | 0   0 10.66 4.50 |
| 5     | 0   2.06 4.60 | 61.36 60.42 61.01 61.16 | 0   0 10.00 11.18 |
| 6     | 0   3.99 4.70 | 58.86 61.05 62.64 64.24 | 0   0 15.57 14.19 |
| 7     | 0   2.68 4.58 | 60.62 63.01 67.62 69.86 | 0   0 1.84 3.05 |
| Average| 0   3.14 4.42 | 62.29 61.86 61.46 64.25 | 0   0 6.32 5.97 |
| Dev   | 0   0.99 1.87 | 2.52 2.32 4.81 3.11 | 0   0 5.75 4.85 |

Notes: M: Morning  E: Evening  ➢: CH4 Peak  ➧: CH4 Min  ☐: The waste dumping process

Table 2. Data comparison based on depth of each pipes in newer waste landfill

| Day   | Pipe 1 (% Vol) | Pipe 2 (% Vol) | Pipe 3 (% Vol) |
|-------|---------------|---------------|---------------|
|       | Morning       | Evening       | Morning       | Evening       | Morning       | Evening       |
| 1     | 57.37 58.75   | 46.28 63.16   | 22.40 31.89   |
| 2     | 64.90 64.68   | 67.72 68.13   | 3.59 5.22     |
| 3     | 65.96 67.84   | 65.39 66.04   | 2.90 9.62     |
| 4     | 61.76 63.66   | 65.00 66.19   | 50.38 50.27   |
| 5     | 63.20 64.87   | 55.20 64.22   | 10.25 42.03   |
| 6     | 63.56 64.82   | 59.38 64.32   | 7.72 14.94    |
| 7     | 61.66 61.88   | 61.18 62.16   | 7.46 17.94    |
| Average| 62.63 63.79   | 60.02 64.89   | 14.96 24.56   |
| Dev   | 2.79 2.84     | 7.38 2.03     | 16.91 17.10   |

Notes: M: Morning  E: Evening  ➢: CH4 Peak  ➧: CH4 Min

According to table 1, the pipe 1 and 3 are still produce CH4 gas if the depth is 3 meters in the morning and evening. While, the pipe 2 can produce CH4 gas when at the depth 1.5 and 3 meters. It caould be happen because the decomposition process of organic material by microbes still occurs
normaly at the area of pipe 2, while the other areas can not produce CH4 sufficiently, because this waste landfill has been already over 20 years (not active zone).

Table 2 shows comparison data according the depth of each pipes in newer waste landfill zone. Here, CH4 gas prouction of pipe 1 and 2 are higher than that of pipe 3, so it has potential to harvest natural gas resources in this area. Meanwhile, pipe 3 there are a different level for observation point. This is influenced by age factor of waste dump. The highest CH4 gas content is at pipe 1 with a heap ages of ± 3 month.

5. Conclusions
Based on the aim of this paper, we conclude that the developed system works properly to monitor, record and give the information about CH4 gas distribution in Klotok’s landfill. The proposed system has indicates the newer area of waste landfill has more potential of CH4 Gas than the older area. Hence, this paper is expected to be a initial research for mapping the CH4 gas in other area, considering the potential of natural gas is needed to be optimized.

6. Acknowlegment
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