Development of an un-powered remote monitoring system of mine waste water

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Abstract

Remote monitoring technology for mine drainage is very important from the perspective of monitoring water quality and water quantity in the context of climate change, reducing the winter monitoring load in areas with heavy snowfall, and saving labour in routine management. Many closed mines are located in areas where there is no radio or electricity, and the construction of remote monitoring systems has required the use of expensive satellite transmissions. This study reports on the development of a low-cost remote monitoring system and the results of one year of monitoring, utilizing low-power long-range transmissions (LPWA).

We have developed a radio-directional, ultra-power-saving telemonitoring system that monitors water pH, EC and flow rate without power distribution and transmits the information to a remote location. The design concept used the private LoRa standard (920 MHz band), a Low Power Wide Area (LPWA), and developed a power-saving transmission program that can operate on natural energy and was installed in a mine. The developed equipment consists of an LPWA transmitter + sensor (henceforth referred to as the transmitter), an LPWA repeater and an LPWA receiver. The sensors were connected to either flow rate, EC or pH sensors, depending on the site. The transmitter and repeater are operated by solar cells and lithium-ion batteries (type 18650, 3.7 V, 3 A). The transmitter reads and transmits sensor data every 30 seconds.

At four mines in Japan, water quality data and other data were continuously transmitted to points between 1 km and 15 km away from the mine. Water quality monitoring could be continued even during periods of snow cover of 1.5 m to 2.5 m at some of the mine sites.

The remote monitoring system has been used to monitor changes in pH, water level and EC even in areas with no power and no signal. Extensions of these systems could lead to future applications such as image transmission and facility operation via transmissions.

Keywords: Low power remote monitoring system, water quality

Introduction

There are approximately 100 closed and abandoned mines in Japan, where environmental management measures such as mine effluent treatment have been implemented. In the environmental management of closed and abandoned mines, it is necessary to routinely monitor the quality and flow rate of mine drainage water. In addition, Typhoon No. 19, which hit some mines in October 2018, caused power outages and collapsed roads used for transporting chemicals and other materials, making it difficult to maintain the functions of mine drainage treatment facilities. There is a growing need to properly monitor the treatment status, even in inaccessible situations. Modelling of 17 years of monitoring data predicted that even after 100 years, the number of mines requiring mine wastewater treatment would change little or not at all (Iwasaki et al. 2021). This implies that the mine drainage treatment should continue for a considerable duration.

In recent years, remote monitoring technology using LoRa standards, has been developed, and in urban factories, remote monitoring technology that transmits sensor measurement results wirelessly has been implemented. On the other hand, many closed mines are located in mountainous areas, where is often no connection to the electricity grid, or where is no coverage of transmissions such as electric power mobile radio waves, making it difficult to apply conventional remote monitoring technologies that require electricity and radio waves.

To address these issues, we are developing a remote monitoring system with radio directionality and ultra-low power consumption, monitoring water quality and quantity without power distribution, and transmitting the information to remote areas, with the aim of saving labour in the management of mine drainage and remote monitoring in the event of a disaster. The design concept is that the system should operate on natural energy, require as little maintenance as possible, and be a transmission device that does not require a license for installation. Fortunately, there is a growing choice of Internet on Things (IoT) technologies available today, and it is important to use the most suitable ones and to adapt the development to the closure of mines and the respective mining environment. This research describes a case study of the development and installation of an un-powered remote monitoring system that operated at 6 old and abandoned mines in Japan.

Methods

Fig. 1 shows the conceptual diagram of the remote monitoring system. Remote monitoring systems consist of sensors, lithium batteries, solar panels, GPS, transmitters, repeaters and receivers.

Power supply

The first choice of power supply that can provide sensor operation and transmission of information without power distribution lines are solar power. There are limited ways to obtain the 10–100 mW required for monitoring, so solar power, small wind turbines and small hydropower are practical for closed mines. Depending on the environment, non-solar cells may also be considered, but as long as there are no restrictions in terms of daylight conditions, solar cells, which have a relatively stable power supply, are preferable. Solar cells will be used, as the site survey confirmed that there are no problems with sunlight conditions.

Means of radio transmission

The means of radio transmission should be selected based on the availability of a transmission network, the amount of

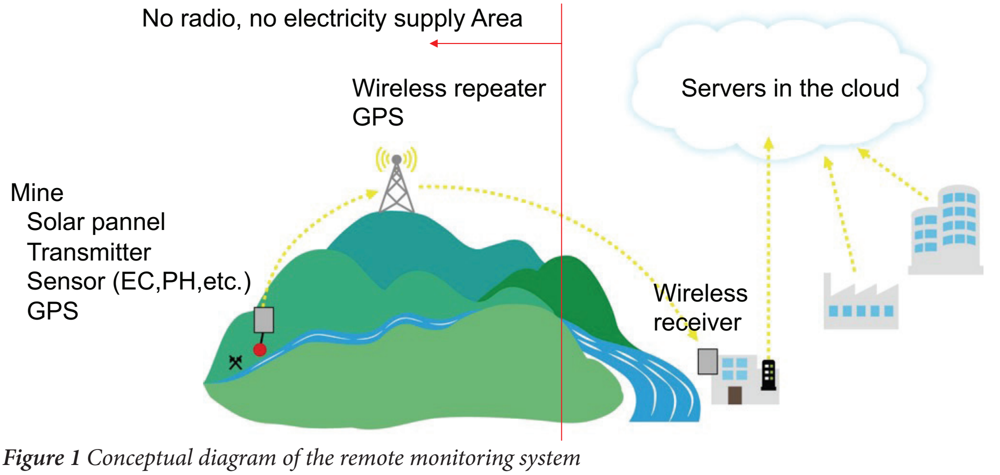

Figure 1 Conceptual diagram of the remote monitoring system

information to be transferred and the transmission distance. For this project the private LoRa standard (920 MHz band), a Low Power Wide Area (LPWA), was adopted. Existing LPWA networks such as Sigfox did not reach the mines, so private LoRa networks were constructed at each mine transmission network. This type of system was considered capable of transmitting the 10 bytes of data per transmission that is typical of a set of collected water quality (e.g. electrical conductivity, pH) and water quantity records.

The appearance of the transmitter and receiver parts of the developed device is shown Fig. 2.

Equipment of radio transmission

The existing LPWA transmitter requires a power supply or a large battery due to its high power consumption, so a new LPWA repeater and an LPWA receiver was developed. The developed equipment consists of a LPWA(LoRa, 20 mW) transmitter + sensor (henceforth referred to as transmitter), an LPWA repeater and an LPWA receiver. The price of the LPWA repeater and an LPWA receiver is within USD 1000 respectively. Two types of sensors (one for water quantity and conductivity, the other for pH) or only one of them connected to the transmitter. The transmitter and repeater(s) are operated by solar cells (1.15 W) and lithium-ion batteries (type 18650, 3.7 V, 3 A). The transmitter reads and transmits sensor data every 30 seconds. The water volume and conductivity are read as digital (serial) data, and the pH sensor has a current output, which is read by the microcontroller through an AD converter. The microcontroller stores the current values calibrated with pH standard solutions, and the read current values are converted to pH values by a quadratic interpolation formula. While the transmitter and repeater are solar powered due to their remote installation the receiver would typically be installed in an environment where electricity is available, such as an office (where a computer may be set up to collect and store or further transmit the received data by internet or cellular service). However, before installing the receiver the location should be tested for incoming signal strength. For this project, the receiver is also powered by a single lithium-ion battery and is fitted with an LCD display to show the RSSI (Received Signal Strength Indicator). The constant operation time with a single lithium-ion battery is about 100 hours, which is sufficient for this investigates. Fig. 2 shows the Appearance of the transmitter and receiver sections; various sensors.

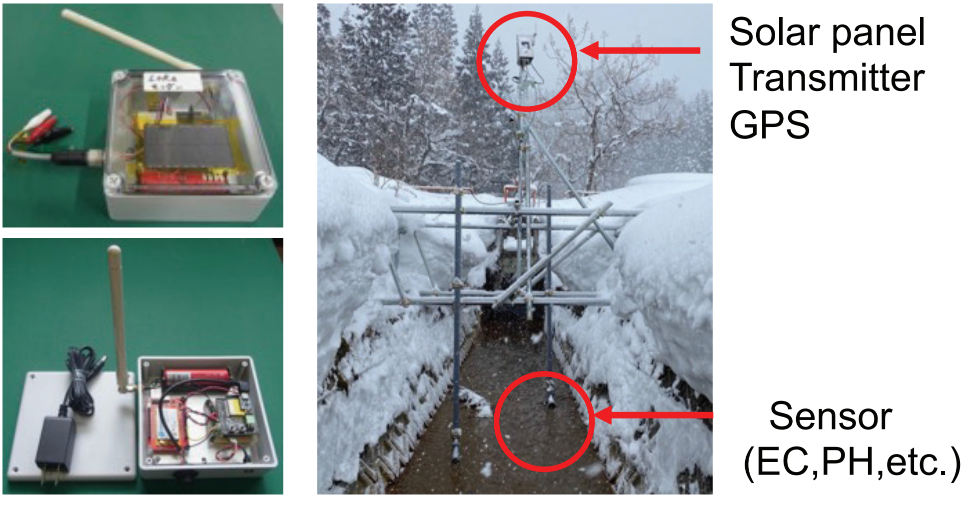

Figure 2 Appearance of the transmitter and receiver sections; various sensors (water quantity, water quality) can be connected to the transmitter section

Table 1 Basic information of the site and remote monitoring system at four mines

Site	Distance m	Mountains between monitoring sites	Number of Repeater	Subject of monitoring	Maximum snow depth	Start date
A	1000	No	0	Flow rate	–	Oct. 2021
B	2000	Yes	1	pH, EC	1.0 m	July 2022
C	15000	Yes	2	pH, EC	2.5 m	Oct. 2022
D	1500	No	1	pH, EC	2.0 m	Jan. 2023
E	4500	Yes	0	EC	–	Aug. 2023
F	7000	Yes	1	Water level, EC	–	Aug. 2023

Equipment installation

Before installation, the transmission situation between the monitoring point, which is the transmitting point, and the office, which is the receiving point, was investigated. The equipment was installed at four mines, taking into account, among other things, signal strength and suitability for monitoring. Table 1 shows the basic information of the site and remote monitoring system at four mines.

Result

Mine A

Monitoring at Mine A started in October 2021 and flow rate monitoring at 1 point has been successful until December 2023.

Mine B

Monitoring at Mine B started in July 2022 and pH and EC monitoring at 1 point has been successful until December 2023.

Mine C

Remote monitoring started at Mine C in October 2022. Monitoring was carried out at three points where pH and EC were measured. This site has a long remote monitoring distance of 15 km and two relay units are connected. In addition, there is snow cover from November to May, with a maximum snow depth of 2.5 m. Fig. 3 shows the the transmitter and solar panel of Mine C in summer and winter. In winter, temperatures can drop below -20 °C.

Remote monitoring at this site did not work until October 2023. The reasons for this were winter battery depletion and transmission errors in the repeater equipment. These issues have been corrected and the system has been operating normally since October 2023.

Mine D

Remote monitoring started at Mine D in January 2023. Monitoring was carried out at three points where pH and EC were measured. The remote monitoring has been operating normally since then, although there was a temporary loss of monitoring due to low battery output in March-April. Fig. 4 shows EC data from the three point at Mine D.

Mine E

Monitoring at Mine E started in August 2023 and EC monitoring at 1 point has been successful until December 2023.

Mine F

Monitoring at Mine F started in August 2023 and water lebel at 1 point has been successful until December 2023.

Conclusions

At four mines in Japan, water quality data and other data were continuously transmitted to points between 1 km and 15 km away from the mine. Water quality monitoring could be continued even during periods of snow cover of 1.5 m to 2.5 m at some of the mines. The remote monitoring system has been used to monitor changes in pH, water level and EC even in areas with no power and no signal. The practical implementation of these technologies will enable inexpensive remote monitoring. As a result, it was confirmed that inexpensive constant monitoring and mine wastewater treatment costs and labour could be reduced.

Figure 3 *The transmitter and solar panel of Mine C (left; Summer, right; winter(2.45 m snow depth))*

Extensions of these systems could lead to future applications such as image transmission and facility operation via transmissions.

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References

Iwasaki, Y., Fukaya, K., Fuchida, S., Matsumoto, S., Araoka, D., Tokoro, C., Yasutaka, T., (2021). Projecting future changes in element concentrations of approximately 100 untreated discharges from legacy mines in Japan by a hierarchical log-linear model. Sci. Total Environ. 786, 147500.

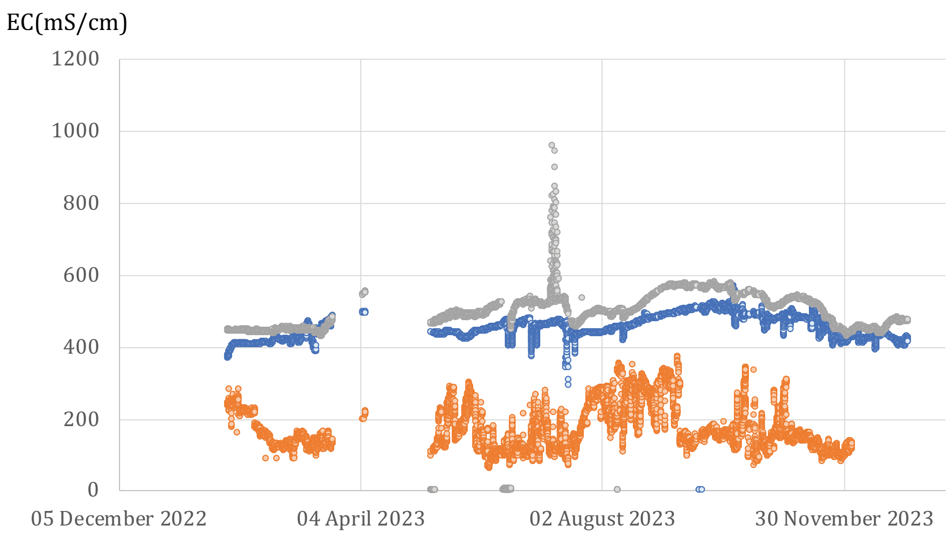

Figure 4 *Remote monitoring data at Mine D from January to December 2023*