Development of a system for monitoring environmental parameters of cities and open areas

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Abstract. This article is devoted to the development of a system for monitoring the state of the ecological environment. The system under development should provide ongoing monitoring of environmental air parameters, both in open areas and in the city, and is designed to timely detect excess concentrations of hazardous substances in the air. A distinctive feature of the created system is high productivity at low economic costs per accounting point. An appropriate selection of the component base and software optimization of the operation algorithms will allow to achieve the maximum data transmission distance over a distance of up to 100 km in an open area. Interim results on the development of a monitoring system are presented, planned tasks for this year are indicated.

Today, the environmental situation in many cities and even nearby open areas is subject to increased pollution due to harmful emissions into the atmosphere by factories and factories, automobiles and other equipment that uses petroleum products for work.

The most dangerous substance resulting from human activities is formaldehyde. The main sources of formaldehyde in the outside air are motor vehicles, chemical plants, wood processing plants, waste incinerators, and it is also contained in tobacco smoke. This gas is colorless with a pungent odor, soluble in water, in our country it is assigned the first hazard class. As a result of many years of research on formaldehyde, it is possible to compile a table with the reaction of the human body to various concentrations of this substance in the air.

Table 1. Reaction of the human body to the concentration of formaldehyde.

| Formaldehyde concentration, mg / m³ | Reaction of the human body                                      |
|------------------------------------|----------------------------------------------------------------|
| 0,03                               | 10% of the subjects felt the smell                             |
| 0,04                               | starts to decrease expiratory flow rate in children (bronchospasm begins - a linear relationship according to the WHO Research) |
0.05 change in the EEG electroencephalogram (brain waves become unnatural) - this concentration is accepted as the maximum permissible in Russia

0.07 in such homes there is an increase in the number of diseases in children with asthma and chronic bronchitis (WHO statistics)

0.1 irritation of the mucous membranes begins (generally accepted concentration at which the smell is felt)

0.2 50% of the subjects felt the smell

0.6 90% of the subjects felt the smell

0.7 all subjects felt eye irritation

1 30% of subjects experienced breathing difficulties (maximum permissible concentration in the air)

2 as a result of a single exposure - eye and nose irritation, headache, nausea for the next 24 hours

4 difficulty breathing, severe lacrimation

40 pulmonary edema, pneumonia, danger to life

60 Lethal concentration

To date, there are several systems for environmental monitoring. In European countries and the United States is actively using the "Worldwide Network of Automated Monitors" uRADMonitor. This system allows real-time monitoring of environmental parameters such as temperature, pressure, humidity, tracking volatile organic substances, noise level in the city, formaldehyde, radiation level, and the content of ultrafine particles. This manufacturer offers several options for device models for organizing a monitoring system. Models of monitoring stations are summarized in table 2.

| Model | A | KIT1 | D | A3 |
|-------|---|------|---|----|
| Used sensors | Dallas DS18B20 (Temperature) SBM20 (γ, X-rays) Hackable (For an additional sensor) | SBM20 (γ, X-rays) GP2Y1010AU0F (Ultrafine particles PM 2.5) LND LND712 (α, β, γ, X-rays) | Bosch BME680 (Temperature, Pressure, Humidity, Volatile Organic Compounds) Winsen ZH03A (Ultrafine particles PM1.0, PM2.5, PM10) Winsen ZE25–O3 (Ozone) Winsen MH-Z19B | Bosch BME280 (Temperature, Pressure, Humidity) Winsen ZH03A (Ultrafine particles PM1.0, PM2.5, PM10) Winsen ZE25–O3 (Ozone) Winsen MH-Z19B |
| Case size, mm | 110×80×24 | 110×60×12 | 110×70×24 | 110×80×24 |
| Supply voltage | External 5V–9V | External 6V–28V | Built-in battery 1500mAh | External 6V–28V |
| Battery life, years | – | – | – | – |
| Operating frequency, MHz | No built-in modem (Ethernet data transfer) | No built-in modem (Ethernet data transfer) | Wi-Fi data transfer | Data transmission via Wi-Fi, Ethernet, GSM, LoRaWAN |
| Cost, rub. | 21,987 | 9,387 | 37,737 | 34,587 |

The disadvantages of these systems include the economic factor, focus on an external power source, which gives its limitations when monitoring in open areas, the ability to transmit data over the air only with the premium model, the closed device architecture without the possibility of replacing sensitive elements, or adding new ones.

Thus, in order to solve existing problems, it was decided to develop our own monitoring system for the water area of Lake Baikal, consisting of sensors for analyzing hydrophysical and meteorological characteristics, a radio modem, a concentrator, and a GSM module.

To constantly monitor the environmental situation and prevent the increase in the concentration of hazardous substances in the air, we have developed a special monitoring system. This system includes a sensitive element (sensor), a radio modem, a hub and a server for storing received data. The data transmission scheme is presented in Figure 1.

![Figure 1. The transmission scheme of the measured data.](image)

As a sensitive element, we use the air quality sensor ZP07-MP503, which has proven itself in various air quality monitoring systems. Appearance is shown in Figure 2.
This sensor has an output UART data interface, operating current less than 60mA, which will create a system with low power consumption. The used sensor for recording formaldehyde level is a semiconductor with a resolution of 10 ppb (0.012458 mg / m³) and an error of ± 5%. Measurement range from 0 ppm to 5 ppm (6.22884 mg / m³). The use of this sensor will detect an increase in the concentration of formaldehyde in the air at levels that are safe for human health, and high sensitivity will help to determine even a small deviation of the concentration of formaldehyde from the norm. A radio modem is used to collect, process and transmit data. The main characteristics are summarized in table 3.

| Parameters               | Prototype          | A3                  |
|--------------------------|--------------------|---------------------|
| Number of channels       | RS-232 to 4        | Closed architecture |
|                          | RS-485 to 32       | Factory set of sensing elements. |
|                          | CAN to 125         |                     |
| Data transfer protocol   | Radio channel, GSM 900/1800 MHz | Optional data transfer: |
|                          |                    | Wi-Fi, Ethernet, LoRaWAN |
| Transmitter power        | radio channel – 100mw | LoRaWAN – 25mw      |
| Distance                 | To 100 km          | n / a               |
| Source of power          | Built in: 3V       | External: 6-28V     |
|                          | External: 9-12V    |                     |
| Cost, rub.               | 5,000-10,000       | 34,587              |

The presence of a built-in GSM transmitter allows you to transfer the received data directly to the information-measuring server without the need to install a hub and additional equipment for data transfer. It is very convenient for use in urban environments. For data transmission in areas with poor coverage of the GSM network or its absence at all, the radio modem has an integrated data transmitter over the radio channel at a frequency of 868 MHz with a data transfer rate of 1.2 Kbps. To date, communication range tests have been conducted in urban environments. As a result, the range of sustainable data transmission was 6 km. Using the CC1120 transceiver in conjunction with the low-noise power amplifier CC1190 will theoretically allow data to be transmitted in an open area over a distance of about 100 km. An experimental confirmation of the data transmission range in the open area.
is planned in the near future. Thanks to the upgraded power supply system, the radio modem can operate independently, from the built-in power supply, and from an external voltage of 9-12V.

This radio modem supports several data exchange interfaces, which allows you to work with a wide range of sensors designed to monitor the environmental situation of the environment, hydrophysical characteristics of water areas and other applications. The connection diagram for several sensors is shown in figure 3.

A short list of supported sensors is given below:

1) CO₂ Gas Sensor
2) CO sensor
3) Flammability sensor
4) Dust Sensor
5) H₂ Sensor
6) Toxic Gas Sensor
7) Air Quality Sensor (VOC)
8) Alcohol Sensor
9) Humidity Sensor
10) Gas Flow Sensor
11) NH₃ Gas Sensor
12) CH₂O Gas sensor
13) O₂ sensor
14) O₃ Gas Sensor
15) SO₂ Gas Sensor
16) H₂S Sensor
17) C₂H₄ Sensor
18) PIR Sensor
19) MEMS Gas Sensor
20) Pressure Sensor

If it is necessary to change the measured air parameter, this radio modem has an open architecture and at any time it is possible to replace one sensor with another without the need for parsing or soldering.

I would like to note that for the work in the conditions of the city of Irkutsk, the entire infrastructure has been prepared, consisting of hubs, GSM modems and an information-measuring system server, which will allow to deploy an environmental monitoring system for air quality in the city in the shortest possible time and at minimal cost.

Thus, this system is applicable for use both in urban conditions and in open areas for the current assessment of the ecological environment.
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