A method for assessing climatic parameters working at low temperatures as an element of technological safety

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Abstract. The development of the Arctic shelf involves the development of mineral resources and monitoring of the environmental situation in the Far North with the implementation of work outdoors in extremely adverse weather conditions. In this case, it is necessary to take into account the stable constancy of negative temperatures. Work on a rotational basis does not solve this problem. This article proposes a methodology for taking into account environmental parameters when assessing the working conditions of nonstationary workplace. As an example, an assessment is given of the workplace of the lineman of main pipeline. It is proposed to use geographic information systems as a technology that allows determining environmental parameters. The responsible person quickly and thoroughly evaluates the work environment based on the existing spatial reference of information to various non-stationary workplaces. The proposed method for assessing and optimizing the time of work will not only minimize technological risks as a whole, but also minimize the damage to the health of workers who are forced to perform work in extremely adverse conditions.

1. Introduction
This article discusses modeling the assessment of the external environment of a worker at low temperatures in the Arctic with the inclusion of climate and light parameters for further assessment of occupational risks. Since all the information for analyzing the climatic indicators of the territory is spatially referenced, the methods and technologies of geo information systems (GIS) are the most effective means of conducting it. Information technologies are tightly integrated into organization management; they replace and facilitate human labor, and increase labor productivity.

A nonstationary workplace is a workplace whose location, as well as its technical equipment, is inconstant. Such a workplace is associated with a particular building or operating facility, and the technical equipment is mobile or portable.

The place of work and environmental monitoring in the Arctic may change during the shift. The lineman of main pipeline profession means working on a rotational basis and periodically traveling to open areas where pipelines are located. The duties of the lineman of main pipeline of the main pipelines include work related to bypassing, monitoring, servicing and repairing the fixed area. Thus, an employee is affected by uncontrolled external environmental conditions.

There are constant threats that negatively affect human activities in the Arctic. These include an increase in the height of wind waves and the appearance of iceberg debris from glaciers on the Arctic islands, which are dangerous for mining facilities and vehicles. Due to sudden changes in temperature and intensification of dangerous hydro meteorological phenomena, it is possible to increase the load on
the employee’s labor process and the number of injuries. Threats also include reducing opportunities and increasing the time period for transporting the personnel of the operating organization to hard-to-reach areas along snowy tracks. Transport interruptions occur due to an increase in the frequency and intensity of abnormal weather events. Soil mobility in permafrost thawing zones causes an increased risk in the operation of buildings and structures, the transport system, including main pipelines. The infrastructure of coastal areas is being disrupted due to increased storm activity, coastal erosion and rising sea levels. In connection with the above, the problem arises of assessing the production environment of a nonstationary workplace.

2. Description of the proposed method using GIS technologies

One of the main tasks of technogenic safety is the assessment of the security of a person performing work in difficult climatic conditions. The problem of assessing damage to human health from environmental factors is one of the important areas of modern hygiene science [1], [2]. Climatic and lighting conditions directly affect the risk of personal injury while the lineman of main pipeline is working. The absence of values of these parameters does not allow to fully identify the dangers that a specialist may encounter during a work shift.

The proposed method consists in determining the parameters of the external environment using GIS technology [3] in order to assess the production environment. The external environmental conditions are subject to long-term observation, statistical analysis and fixing by months and years to consider all combinations of weather conditions. The main advantage of GIS is that the user can analyze the meteorological conditions of any day, get the results of the calculation of global and regional meteorological models. The method allows you to evaluate any decision made from the position of time and resource costs and establish a connection with the results of the action [4].

Among the climate parameters that affect the employee, it is necessary to distinguish the following: temperature, air pressure, humidity, wind speed. Such climate parameters in various combinations can be dangerous and harmful production factors. Given the extreme nature of these values for regions of Arctic latitudes, taking these parameters into account can be crucial for planning and conducting work [5].

Currently, GIS technology, methods of geographic information mapping, mathematical and cartographic modeling are widespread and are used to solve various practical problems [6].

The use of GIS technologies is advisable in connection with their wide capabilities:
- creation and updating of databases on natural environments;
- implementation of spatio-temporal analysis and joint interpretation of qualitative, quantitative features recorded on the ground;
- identification of the relationship between the studied phenomena;
- synthesis of thematic, integrated and specialized cartographic materials;
- presentation of the processed and clearly interpreted information for decision-makers.

Thus, the GIS integrates spatial information and other types of information into a single system to solve the spatiotemporal tasks of managing [4] the safety of working personnel during work in extremely adverse weather conditions.

Taking into account the statistical geophysical data obtained with of GIS, it is possible to assess the production environment [7] and, subsequently, assess professional risks [8] of nonstationary workplace, which include all types of monitoring works. Such an approach will minimize or even eliminate the threats to personnel [9] under certain climatic parameters that are specific to the Far North regions.

Below is our proposed algorithm for assessing the environmental parameters of nonstationary workplace of a lineman of main pipeline (Fig. 1).

1. The crew foreman receives service call for repair work on the fixed area.
2. The crew foreman gives the task to the responsible person to assess the working environment and identify the level of danger.
3. The responsible person uses GIS technology.
4. The GIS provides information on meteorological parameters (temperature, humidity, wind speed, air pressure), precipitation, and daylight hours in the area of planned work.

5. The responsible person analyzes the information received, evaluates the production environment, identifies threats and determines the start time of the work and a list of recommended activities. The responsible person to carry out these tasks must have appropriate professional training [10].

6. The responsible person provides information on the level of danger of the working environment to the crew foreman.

7. The crew foreman sends workers to jobs.

8. Workers at the direction of the crew foreman begin to work.

**Figure 1.** Algorithm for assessing the environmental parameters of nonstationary workplace

In the Arctic climate, the main attention should be paid to the "Seasonality" parameter. In this geographical area, seasonality affects temperature stability, precipitation, hydrological phenomena, icy-frost deposits and wind speed. The parameter "Seasonality" is proposed to be divided into 2 categories "Stable" and "Unstable" and assign numerical rating for the subsequent calculation of the assessment of professional risks.

The next parameter "Precipitation" can be divided into categories: none, average and maximum. For a better identification of threats at the workplace, the category "Maximum" can be divided depending on the season into such meteorological phenomena as a blizzard, hail. Next, you should evaluate the wind speed, dividing them into subcategories. The next important parameter is “Light environment”. Light has a great influence on the work, for example, insufficient lighting leads to overstrain of the
visual apparatus, as a result of which vision is impaired, and oversaturated - it tires the nervous system. The use of lighting devices can cause such unpleasant effects as stroboscopic, in hard, contrasting light, dangerous elements can appear in the shade, and also overexposure and reflection of the light wave, thereby leading to injury.

In this method, it is proposed to use a point system. The use of a point system allows you to develop a method for assessing the production environment of a non-stationary workplace.

First of all, it is necessary to study the temperature regime of this territory. To do this, analyzed the statistical data of the GIS and determined the temperature ranges. As a result, the following graph was obtained (Fig. 2), according to which a correction coefficient was obtained (Table 1).

![Figure 2. The number of days in a year with the corresponding temperature ranges for the seasons according to GIS data](image)

Table 1 presents the temperature ranking by intervals. Depending on the season, certain points are assigned, in addition, the average seasonal frequency of temperature is taken into account (data for 2019). In Table 2, the corresponding parameters are assigned to the characteristics of the parameters of the production environment.

The following minimum values of -2, maximum values of 64 were established as numerical values (points) of the industrial environment parameters. Intermediate values (4,8,16,32) are directly
proportional to the increase in the level of danger. This will simplify the identification of hazards that depend on meteorological conditions.

Table 1. The point system of the parameter "Temperature"

| Temperature, °С | Points | Coefficients |
|-----------------|--------|--------------|
|                 | W      | Sp | S | Au | W | Sp | S | Au |
| from -35        | 64     | 64 | 64 | 64 | 0,71 | 0 | 0 | 0 |
| from -13 to -34,9 | 32 | 32 | 32 | 32 | 1,23 | 0,82 | 0 | 0 |
| from -12,9 to -7 | 8 | 16 | 16 | 16 | 0,91 | 1,58 | 0 | 0,45 |
| from -6,9 to 0  | 4 | 4 | 16 | 4 | 0,15 | 0,46 | 0 | 1,02 |
| from 0,1 to 8   | 4 | 4 | 6 | 4 | 0 | 0,14 | 0,02 | 1,39 |
| from 8,1 to 15  | 6 | 2 | 4 | 2 | 0 | 0 | 1,35 | 0,14 |
| from 15,1 to 20,00 | 8 | 2 | 2 | 4 | 0 | 0 | 0,72 | 0 |
| from 20,1 to 25 | 8 | 4 | 8 | 4 | 0 | 0 | 0,62 | 0 |
| from 25,1       | 8 | 8 | 32 | 8 | 0 | 0 | 0,29 | 0 |

(Where «W» - winter; «Sp» - spring; «S» - summer; «Au» - autumn)

Table 2. The point system of the parameters of the production environment

| Production Environment Parameters | Points |
|-----------------------------------|--------|
| Сезонность                        |        |
| Winter                            | Stable/Unstable (during work shift) | 32/64 |
| Spring                            | Stable/Unstable (during work shift) | 8/16 |
| Summer                            | Stable/Unstable (during work shift) | 2/8 |
| Autumn                            | Stable/Unstable (during work shift) | 8/16 |
| Precipitation                     | none/average/maximum | 2/4/32 |
| Wind speed, m/s                   | 0/from 2,3 to 2,9/ from 3 to 10/ from 10,1 to 15/ from 15 | 2/4/16/32/64 |
| Air pressure                      | low/normal(760 mmHg)/high | 8/2/8 |
| Lighting                          | twilight, scattered | 4 |
|                                  | twilight, contrast (hard) | 8 |
|                                  | dark, scattered | 16 |
|                                  | dark, contrast (hard) | 32 |
| Daylight                          | bright, scattered | 2 |
|                                  | bright, contrast (hard) | 8 |

* stable conditions – the ambient temperature during the work shift does not change by more than 5 degrees, precipitation is not expected;
* unstable conditions - the ambient temperature during the work shift changes by more than 5 degrees, precipitation is expected.

According to the information received, the calculation is carried out according to the formula (1):

\[ L = P_1 + P_2 * k + P_3 + P_4 + P_5 + P_6, \]  \quad (1)

where \( P_1 \) - the number of points for the parameter "Seasonality";
\( P_2 \) – the number of points in the parameter "Temperature";
\( k \) – correction coefficient;
P3 – the number of points for the parameter «Precipitation»;
P4 – the number of points for the parameter «Wind speed»;
P5 – the number of points for the parameter «Air pressure»;
P6 – the number of points for the parameter «Light environment».

The responsible person determines the values of these parameters using GIS. According to table 1 selects the temperature range, including the current value of the ambient temperature in the place of the planned work. In accordance with the current time of the year, the corresponding number of points is determined, while taking into account the stability of climatic conditions. The obtained number of points is multiplied by a correction coefficient. The number of points for the remaining parameters are taken according to table 2.

As a result of calculations using this formula (1), the total point obtained, which determines the level of danger of the working environment (Table 3). Then, according to the appropriate level of danger, a list of measures is developed to protect personnel from the negative effects of dangerous and harmful factors.

**Table 3. Ranking hazard levels of the production environment**

| Hazard level | Characteristic of production environment hazard level | Remedial measures |
|--------------|------------------------------------------------------|------------------|
| 0-15         | Small or none                                       | Remedial measures are not required. You can start work after receiving the service call. |
| 15-75        | Temperate                                            | You can start work after receiving service call, you need constant monitoring of the labor process. |
| 75-100       | Serious                                              | You can start working after applying additional safety measures, you need constant monitoring of the labor process. |
| 100-150      | High                                                 | A specific time for the execution of work is assigned, additional safety measures are applied, constant monitoring of the labor process, monitoring of meteorological parameters are required. |
| больше 150  | Extreme                                              | You can't work; monitoring meteorological parameters; expecting a reduction in the level of danger of the production environment. |

Consider the following situation: service call for repair work were received at three different points on a fixed area. Based on the data obtained using GIS, an assessment of the working environment was carried out (Table 4)

**Table 4. Assessment of the production environment**

| Production Environment Parameters | Workplace 1 GIS indications | Workplace 2 GIS indications | Workplace 3 GIS indications | Points |
|-----------------------------------|-----------------------------|-----------------------------|-----------------------------|--------|
| Время прибытия, мин              | 15                          | 30                          | 40                          |        |
| Spring                           | unstable                    | unstable                    | unstable                    |        |
| Temperature, °C                  | -25                         | 26,24                       | -19                         |        |
| Precipitation, mm                | none                        | 2                           | none                        |        |
| Wind speed, m/s                  | 7,8                         | 16                          | 3,2                         |        |
| Air pressure, mmHg               | 745                         | 8                           | 745                         |        |
## Production Environment Parameters

| Workplace 1 | Workplace 2 | Workplace 3 |
|-------------|-------------|-------------|
| GIS indications | Points | GIS indications | Points | GIS indications | Points |
| Время прибытия, мин | 15 | 30 | 40 |
| Light environment | daylight, cloudy, bright, scattered | daylight, bright, contrast (hard) | artificial lighting, twilight, contrast (hard) |
| Total | 86,24 | 92,24 | 108,24 |

As a result of the assessment of the working environment, it was found that the hazard level of the working environment at 1 and 2 workplaces – serious. You can start working after applying additional safety measures, you need constant monitoring of the labor process. Danger level at 3 workplaces - high. A specific time for the execution of work is assigned, additional safety measures are applied, constant monitoring of the labor process, monitoring of meteorological parameters are required.

### 3. Conclusion
GIS makes it possible to quickly respond to any emerging situation in any territory with the receipt of all necessary cartographic and climatic information on it. The GIS database can be used to further develop strategies to reduce the negative impact of climate factors on personnel employed in nonstationary workplaces.

Such an approach based on the use of GIS allows you to quickly and reliably obtain meteorological information about the estimated area of the working area for assessing the production environment of nonstationary workplaces.

If you fully evaluate the production environment, then subsequently identification of hazards to calculate the assessment of occupational risks will prevent threats associated with uncontrolled meteorological conditions, securing the life of the employee. This is of paramount importance when carrying out any kind of work in the climate of the Arctic at nonstationary workplaces.

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