Evaluation of the Geoecological Factors Influence on the Foundations’ Precipitation, Located on Anisotropic Soil Bases

O Korobova*1 and L Maksimenko1

1Novosibirsk State University of Architecture and Civil Engineering (Sibstrin), Novosibirsk, 630008, Russia
E-mail: *o.korobova@sibstrin.ru

Abstract. The research work considers the problems associated with Geoecological factors, related to the soil mechanics and foundation engineering. The scientific relevance is revealed, taking under consideration the fact, that special attention is paid to its role and the possibility of using geneecology in solving environmental problems in modern conditions in soil mechanics development, analyzing and assessing the changes, taking place under the influence of natural and man-made impact, in the rational use of water, land, mineral and energy resources; in ensuring the safe living of people and reducing harmful effects on the environment as a result of natural and man-made disasters and various disasters, as well. In addition, the influence of Geoecological factors on the precipitation of foundations, calculated, concerning deformation anisotropy of base soils, is considered. The main types of Geoecological factors and the negative consequences of all these factors influence are given. The analysis of raising and lowering groundwater level effect on the carrying capacity of anisotropic soil foundations and precipitation of foundations was carried out. The role and necessity of using environmental impact assessment, as well as a comprehensive method of research and forecasting development of geological risk factors, are noted.

1. Introduction

1.1. Environment Impact on Soils Structural Properties

Incorrect planning of built-up areas, shortcomings in the design, construction and operation of buildings and structures, changes in geological and hydrogeological conditions are observed everywhere [1-4], due to human economic activity. This leads to a decrease in the strength of the base soils, and consequently, to a violation of their stability.

Problems, related to environmental factors, occupy an important place in hydrogeology and geotechnics, especially in the case of ground foundations [1]. The main solutions to the problems in the field of Geneecology are the following:

- reliable assessment and analysis of changes, occurring in geospheres under the influence of natural and man-made impacts;
- rational use of water, land, mineral and energy resources;
- live ensuring and reducing the harmful impact on the environment as a result of natural and man-made disasters.
The most typical factors that do not contribute to these ones (from the point of soil mechanics view) include:

- water balance violation of surface and underground waters, caused by infiltration of technological, industrial and household wastewater leaks into the ground, increasing its humidity, and then forming local groundwater horizons and, as an inevitable consequence, raising the groundwater level. Such consequences can occur during the construction of reservoirs, filling the bottom of the pit the planning process of earthworks production, using "wet" processes in production, changing the terrain and the conditions of precipitation runoff as a consequence.

The most significant changes in the hydrogeological conditions of the region may occur as a result of underground water retention spread from storage facilities, ash dumps, tailings dumps, and other hydraulic structures [5]. The resulting flooding leads to waterlogging of buildings and structures foundations, to their additional precipitation and associated negative consequences. Increasing the level of ground water to the foundation sole level may cause an increase in areas with plastic deformations of the soil under the edges of buildings and structures foundations and, a decrease in the strength and deformation characteristics of the soil, and a decrease in the load-bearing capacity of the base’s foundations. This is especially true for subsidence, loess-like soils, where subsidence may be even stronger and reach catastrophic values for buildings and structures. The rise of the soil surface and structures is characteristic for swollen soils, in similar cases.

Lowering of the ground water level, which occurs in pumping oil case, gas and water, mining through wells, construction of deep open pits and mines, during the operation of water intake wells, it leads to deformation of the earth’s surface and a significant change in the direction and intensity of the filtration forces. In this case, in addition to pollution, the stress state of mountain ranges changes and their stability is violated. The extraction and use of minerals, taking into account geo-environmental factors, requires a review of the entire strategy for their production and should serve as a powerful incentive for the conservation of natural resources and more rational use. The construction of industrial complexes, cities, their intensive development, the construction of unique high-rise buildings leads to an irreversible change in the position of the groundwater horizon. In this regard, city infrastructure development and industrial facilities operation in areas of existing high groundwater level is observed everywhere their reduction and vice versa, where the underground waters are deep, and sometimes even virtually absent, there is their appearance, the flooding of soils and rising groundwater levels. The horizon lowering of groundwater level is caused by a decrease in precipitation filtration into the ground bases. This can occur due to the development of a territory surface, installation of drainage systems, drainage of soil by sewage collectors, various underground utilities and even underground metro lines, and other reasons. Lowering the level of underground water always in all cases causes precipitation of ground bases and buildings and structures. Precipitation of even greater magnitude can occur when the soil layer is formed under water and has never been drained before [5].

In the operation of canals and reservoirs, their slopes are often flooded, which leads to a decrease in the stability coefficient and often to their stability violation. The most negative is the rapid decrease in water in the reservoir or ditch, ensuring the stability of slopes, and this is especially evident when slope soils have high water permeability. In this case, slope is in a state of practically complete water saturation, and as a result of filtering water from the slope, significant filtration forces arise shift the slope and reduce its stability.

As a result of unorganized placement of waste (solid, alluvial, liquid, etc.), landfills, lack of engineering and environmental protection measures to prepare places for storage and disposal of food and industrial waste on the Earth's surface, urban landfills turn into pockets of active air pollution and worsen the sanitary condition of urban areas. In agriculture, it is also necessary to process, remove or dispose of a large amount of solid waste. Any human activity has an impact on the natural
environment. Special attention should be paid to artificial objects, which include buildings and structures, reclamation systems, roads, etc. These objects are long-term and directly in contact with the surrounding nature.

An important negative contribution is made by: a dense network of water and sewer pipes that leak from time to time, which leads to the rise of underground water, a continuous network of urban development where underground water is pumped out, which result is that almost all major cities are located in the so-called "depression funnels", various engineering structures construction, metro construction, laying of automobile and Railways, oil and gas pipelines, power lines, etc.-all these factors can be attributed to factors that affect the nature around us.

One of the most important problems of Geocology is also the storage of natural resources that ensure the existence and development of the biosphere-water, bio-productive soil, minerals and ores, energy and heat carriers (oil, gas, coal, peat, etc.). The reserves and state of our planet's resources are of serious concern because of the continued growth in resource consumption and the insufficient and often poor-quality use of resource-saving and resource-protection measures. First of all, this can be attributed to water resources – the main source of drinking water supply. Currently, more than 50% of fresh water is polluted. Most often, groundwater is contaminated with nitrogen compounds, sulfates, chlorides, petroleum products, and other wastes of various types of industrial production, high pollution with toxic elements, dangerous for their stability and migration ability.

Land resources and soil cover are not in the best position. As a result of water and wind erosion, pollution and soil degradation, agricultural land degradation is observed everywhere. In Western Siberia, the desolation process of lands is developing particularly rapidly due to oil and gas production

### 2. Materials and methods

#### 2.1. Consideration of Geocological Factors in the Calculation of Soil Bases

It is especially important to be able to correctly analyze the phenomena that occur, assessing damage to foundations by groundwater, which should lead to the research creation and forecasting methods [6]. The main method of analysis, used in Geocology, is a system analysis of an environmental assessment of processes and phenomena general relationships. Currently, the most common types of destruction and phenomena are in the 1\textsuperscript{st} table “Factors that cause damage to structures”

| Cause of damage            | Impact of groundwater | Damage frequency, % |
|----------------------------|-----------------------|---------------------|
| Wobble mirrors of underground waters | direct | 2.9 |
| Drainage                   | direct                | 2.7 |
| Soil Freezing              | direct                | 0.7 |
| Sewers Damage              | indirect              | 25.1 |
| Water Pipes Damage         | indirect              | 10.6 |
| Water drainage pipes       | indirect              | 15.2 |
| Process water              | indirect              | 2.7 |
| Surface water              | indirect              | 10.6 |
| Change in the soil volume (swelling) | indirect | 8.2 |
| Other reasons              | indirect              | 21.3 |
In this regard, a more reliable and accurate forecast of possible changes in the hydrogeological regime is needed, which can be achieved, including taking into account the anisotropy of the base soils. As it was found, further aggravates the negative consequences caused by the imbalance in nature regimes [8], [9]. Thus, the impact of changes in the groundwater regime on the load-bearing capacity of anisotropic soil bases and foundation sediments was evaluated according to experimental and theoretical studies of the Novosibirsk and Barnaul soils [8]. As it is known, the increase in the level of ground water is associated with soil waterlogging. The authors of the studies have found that an increase in groundwater horizon directly at sole and within foundations’ depth leads to an increase in areas of plastic deformation under their edges.

These data are in good agreement with the research results of other authors, for example, P. L. Ivanov [5], who dealt with the problems of territories flooding and isotropic soil flooding arrays. In the case of anisotropic soils, this pattern becomes even more obvious.

The obtained results can be explained by the fact, that the compressive stresses from the soil’s own weight are reduced, after taking into account the weighing action of water (since the soil is in a watered state).

\[
P_{1/4} = \pi \cdot (\gamma \cdot h + 0.25 \cdot b \cdot \gamma + c/\tan \phi) / (\tan \phi - \pi/2 + \phi) + \gamma \cdot h, \quad (1)
\]

\[
R = \gamma_c \cdot \gamma_s \cdot b \cdot \gamma_{sb} + M_q \cdot h \cdot \gamma_I + M_c \cdot c. \quad (2)
\]

where \( P_{1/4} \) – critical edge load assuming the development of the ultimate stress state region to depth \( z_{max} = b/4 \) (where \( b \) – foundation width); \( R \) – design soil resistance of the foundation.

In case of possible watering of the base soil, \( \gamma \) value of dependencies (1) and (2) is replaced by \( \gamma_{sb} \) [5]:

Dependency (2) is written in the form, provided in SP 22.13330.2016. In the case discussed above, as well as in the presence of soil loading, the calculated resistance \( R \) is significantly reduced [6]. If the soil has deformation anisotropy, within the substituting in formulas (1) and (2), instead of \( b \)–the width of the foundation sole, located on an isotropic soil, the values \( b \) – the width of the foundation sole, located on an anisotropic base. Then \( R \) value will decrease even more. As a result of soil watering, there is a decrease in strength characteristics, which leads to a decrease in the calculated resistance by 1.9 – 2.0 times, and in general, to a decrease in the bases bearing capacity. Otherwise, anisotropy has a significant impact on value of the ground base calculated resistance \( R \), changing its value by 1.5 ... 3.0 times. For loess-like subsidence groups, this trend is further exacerbated. The development of plastic deformation regions is shown in figure 1.

![Figure 1. Development of plastic deformation areas: a-soil in its natural state, b-watered soil, C-anisotropic soil, d-loess-like subsidence soil.](image)

The effect of rising ground water levels on foundation sediments is also noticeable, and the values of deformation modules decrease, both in the vertical and horizontal directions, as well as a decrease
...in the value of the deformation anisotropy index as it was shown earlier [6], taking into account the deformation anisotropy, for example, for loess-like subsidence soil, with an increase in soil moisture. The results of the study are presented in table 2 (where $E_z$ and $E_x$ are the modules of soil deformation in the vertical and horizontal directions).

Close attention in specific geotechnical, climatic and hydrogeological conditions have already been identified. Groundwater can have a detrimental effect on the Foundation, directly or indirectly. Direct impact is associated with direct contact or exposure to ground flow, indirect impact occurs when the ground water level is below the Foundation level.

When analyzing a large number of structures [7], table 1 was compiled, which evaluated the role of factors that cause damage to structures, as well as reflecting the causes and repeatability of typical destructions. The data shown in table 1 suggest that groundwater is the decisive factor in the damage to about 80% of all buildings and structures, with 6% of the damage caused by direct impact of groundwater and 72% indirect.

Table 2. Influence of natural moisture content on deformation of Anisotropy soil.

| Pressure $\sigma$, MPa | Natural moisture, W | Deformation modulus | Anisotropy index $\alpha = \frac{E_z}{E_x}$ |
|----------------------|---------------------|---------------------|------------------------------------------|
| 0.3                  | 0.13                | 6.36                | 4.16 | 1.53 |
| 0.3                  | 0.23                | 4.36                | 3.22 | 1.35 |
| 0.3                  | 0.28                | 4.03                | 3.12 | 1.29 |

Significantly influence the increase of level of ground waters and Reduction of the deformation modulus of the moist soil leads to increased deformation of the buildings: for example, for one of the enterprises of Novosibirsk, the precipitate of soil at natural humidity amounted to $s = 0.040, 0.030$ and m, and the watering of soil $-\text{OBV} = 0.078, 0.055$ m. Precipitation and foundations, in the case of flooded soil increased by approximately 50% relative to precipitation, soil natural moisture.

The change in the base precipitation when the ground water level rises is shown in figure 2.

Figure 2. "Draught-load" Graph: 1-soil in its natural state, 2-watered soil, 3-anisotropic soil.

Design settlement can significantly exceed the maximum allowable according to SP 22.13330.2016, taking into account the deformation anisotropy (especially when the anisotropy index $\alpha > 1$), which happen in the case under consideration, and the relative difference in the settlements also significantly exceed the maximum allowable according to SP 22.13330.2016: $(\Delta s/L) = 0.0072 > (\Delta s/L)_u = 0.002$.

In the case of flooding and loess-like subsidence rocks flooding, additional precipitation or subsidence is even more pronounced, and if we take into account the pronounced anisotropy of their deformation properties (for example, for the studied loess soils of Barnaul, the anisotropy index $\alpha =$...
1.97) [6], in this case, the deformation of the base can lead to an emergency state of a building or structure.

The change in base precipitation when the ground water level rises is shown in figure 2.

It should be noted that as cities develop and industrial enterprises operate, there is a widespread decrease in the level of ground water in areas with a high level of groundwater. The lowering of the ground water may be caused by reduction of precipitation infiltration into the soil as a result of paving and building area, the drainage depth of the soil sewer, various underground utilities, subway lines-polythene, as well as water wells, development of oil and gas deposits, construction of mines and quarries, etc. [5]. In all cases, the lowering of the ground water level causes deformations of buildings and structures, located on the surface. In this case, the reverse of the above-described process takes place in the ground base, i.e. the weighing effect of water disappears, which result is the stresses from the ground's own weight (within the limits of lowering the ground horizon) increase by about 2 times. Deformations increase, as shown by the study, from 10 % to 40 %, taking into account the anisotropy of the soil, (figure 3).

![Figure 3](image)

**Figure 3.** Stress distribution when groundwater is lowered: 1 – the stress from the ground's own weight before lowering, 2-the same after lowering, 3-additional compressive stresses from the action of filtration forces.

Pumping water from wells, oil and gas production also leads to the development of sediment on the ground surface, buildings and structures [5]. At the same time (under the influence of filtration forces), additional compressive stresses are created that cause soil compaction and surface sedimentation around wells, i.e., in addition to lowering the groundwater level, water filtration develops in the depth of the pumping zone. It should be noted that the soils of the Barnaul territory has a well-defined anisotropy of filtration and compressibility, which have a significant impact on the load-bearing capacity and deformability of the bases.

### 3. Results

Therefore, it can be argued that forecasting the impact of Geoecological conditions on the load-bearing capacity of soil formations and foundation sediments is currently relevant and timely. Problems, related to groundwater, occupy an important place in hydrogeology and geotechnics. However, both the theoretical development and the practical application of these two sciences have occurred in relative isolation. Hydrogeology deals primarily with forecasting water levels, for example, during spring floods, or levels during the growing season. Geotechnical tasks (drainage of underground spaces, drainage of mine workings, construction of a drainage network, changes in the physical properties of soils with changes in water levels, etc.) determine the interest in predicting the maximum and construction water levels in frosty period, in determining the direction of groundwater flow and the most favorable in terms of drainage, construction time. Statistical studies have shown that 80% of the damage to buildings, caused by geometric causes, is due to the position or fluctuations of the ground water level.

Due to the date, studies have already been initiated that best match the analysis methods and tasks of geotechnics and form geotechnical methodology basis. Research largely can be facilitated favorable situation: the density of the existing network provides precise information on the number of
groundwater characteristics (regulation of water levels, direction of flow, groundwater slope, chemical composition, spatial position, water nosego layer, etc.) at the site of the designed object.

The growing interest in problems related to industrial and civil construction, the ever-growing influence of human activity on the water regime, the already existing significant time series of observations on wells, the introduction of probability theory into practice and the use of computer technology mean that fresh ideas and generalizations are urgently needed at the current stage of knowledge development. Solving problems at a higher level requires at the same time a gradual convergence of both concepts and methods of two sciences and an increasing application of scientific knowledge in related fields: Geology, soil science and meteorology.

Taking into account anisotropy is also necessary, solving the utilization and storage problem of various waste, since a characteristic feature of all its forms (dumps, dumps, storage facilities, etc.) is their heterogeneity in density, composition, and, as a consequence, in strength and deformability. In these cases, it is natural to expect a significant manifestation of anisotropy.

Our country has introduced environmental expertise as a comprehensive assessment system of possible environmental and socio-economic consequences of all ongoing projects, including the reconstruction of various objects and structures [10], which is carried out in accordance with approved instructions and rules. As the experience of different authors [5] shows in commissions on various disasters and accidents related to violations of the soil bases strength and the stability of buildings and structures, they are usually not explained by any one cause, but there are the simultaneous action of a group of factors, so only a comprehensive analysis with a wide range of specialists involvement should be used.

It is necessary to develop complex methods for the study of geological risk factors in the territories of industrial centers, and there is a need to create a unified system for monitoring the natural environment of Western Siberia. This area requires further scientific research and is of great practical importance.

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