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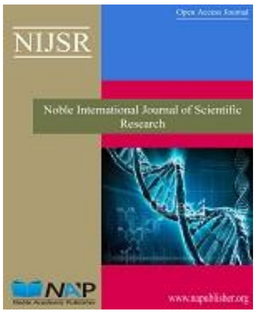

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ENVIRONMENTAL SAFETY OF BUILDING DEVELOPMENT ON THE KHARKIV CITY FLOODING AREAS EXAMPLE

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ABSTRACT: Paper treats the issue of environmentally dangerous building development on the flooding and flood-prone areas on example of Kharkiv city. Aim is to assess the urban development impact on the groundwater regime at Kharkiv. Focus is on the rate calculation of the spread flood phenomenon and the material losses risk from flooding on the researched area. The risk of material losses from flooding on the entire research area is 12,26% per year. The rate of flood phenomena spreading per year for research territory has been calculated, and the flooding area increases on 1% per year.

Keywords: Groundwater Regime, Urban Development, Flooding, The Material Losses Risk, Groundwater Level, Environmental Safety.

1. INTRODUCTION

At present, in Ukraine, the active baking zone territories are used for the new facilities building. It is important to note the area of flooding within the territory of Ukraine amounted about 79,44 thousand km2 (7,9 million hectares) in 2011-2014, and the number of flooded settlements amounted about 4702 [1-3]. Already in 2017 the flooding area is 89,062 thousand km2 (8, 9 million hectares), and the number of flooded settlements is 4747 [4]. This list starts with the big cities of Ukraine.

Kharkiv is indicative of the flooding state for urban areas. The characteristic feature of the Kharkiv territory defined during the last decades is the high level of groundwater, which causes flooding of a large city part. The flooded area in Kharkiv in the early 80's according to [5] was 4,7 thousand hectares, and potentially flooded lands – 8,8 thousand hectares. And for the period from 2010 to 2014, the flooding area has increased to 19 thousand hectares [2, 3].

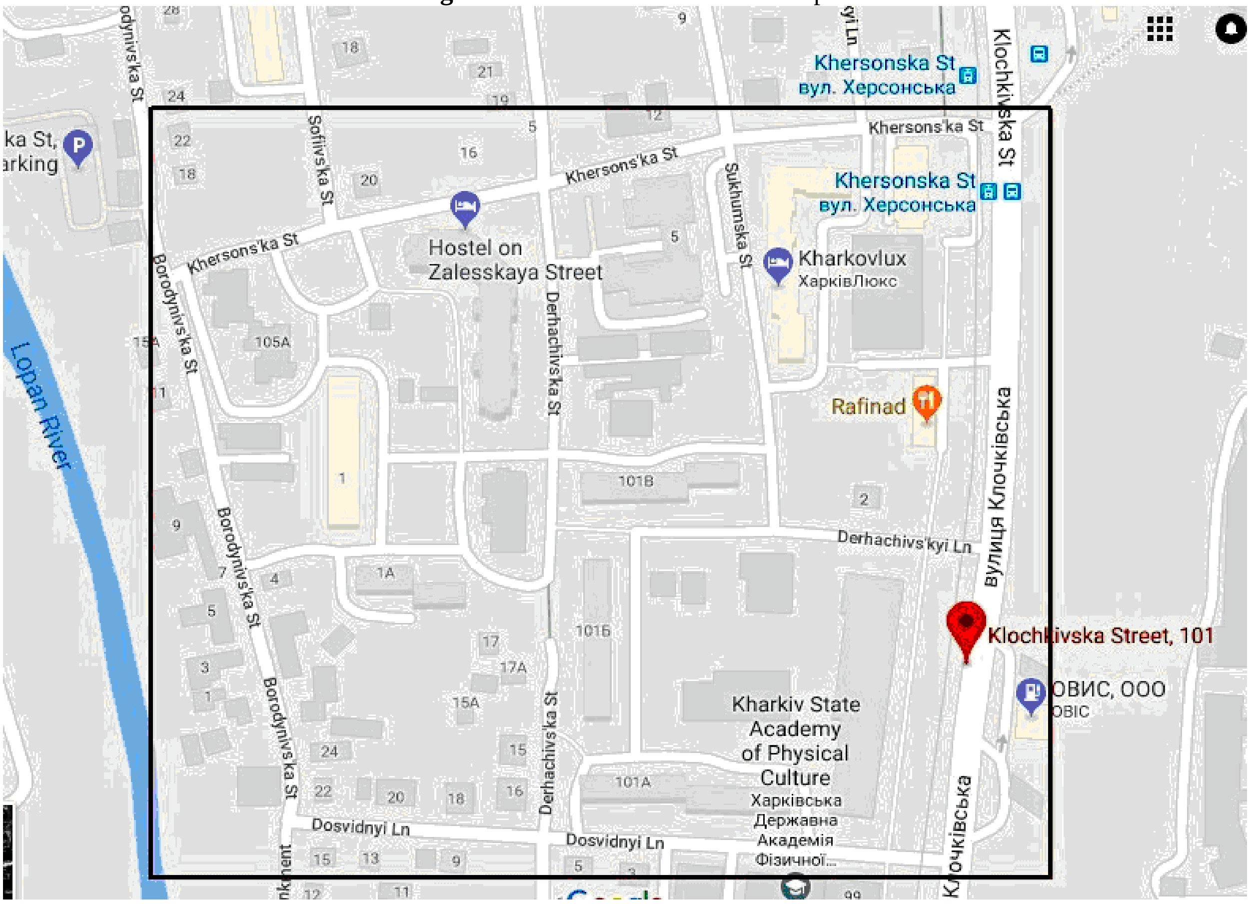
Flooding leads to the underground communications materials destruction, pollution of the entire underground cities space, in particular the upper groundwater horizons, the swampy areas appearing and flooding of underground premises in residential buildings. Such processes provoke the development of ecologically dangerous biological and physical-chemical phenomena: active reproduction of bloodsucking insects, the ascomycetes appearance, the poisonous vapors in the air formation, which adversely affects the population health and causes significant material damage.

Many scientists and specialists have been treating the causes and consequences of flooding territories, such as Abramov, et al. [6], Belousova [7], Dzektser and Bolgov [8], Kremez [9], Yakovlev, et al. [10]. However, the definition of the complex technological influence of building on the groundwater regime was not carried out. Therefore, the purpose of the work is to assess the impact of urban development on the groundwater regime, for example in Kharkiv.

2. RESEARCH METHODS

It has been treated in the paper the plot of the Kharkiv city north-western part, within the Shevchenkivsky (formerly Dzerzhinsky) district. The plot is limited by the streets of Klochkivskaya, Borodinovskaya, Khersonska and per. Dosvidniy. The investigated territory is geomorphologically timed to the Lopan River floodplain. The Kharkiv research area map has been presented on Fig. 1.

Fig. 1. The Kharkiv research area map.



Source: Author

In the 1980s, the research area of the Kharkiv city was built mainly by private single-storey buildings and household buildings. Caves depth to 2,0 m periodically flooded with water at 0,2-1,0 m from the floor [11, 12].

Private houses subsequently demolished and large-scale construction of a multi-storey buildings new block and engineering systems was started.

At the beginning of the development of the research area in 2004-2006, it represented a diverse functional use of the territory. Part of the site was occupied with empty bushes and trees, the part was complicated by dumps of soil in height about 2 m, part was waterlogged and part was freed from private development and planned with bulk soils up to 4,0 m thick. Also, a small part was occupied by a spontaneous construction rubbish dump [13, 14].

Today, the entire research area is built up with multi-storey buildings, which were put into operation, the residential area was asphalted (except Borodinovskaya Street) and landscaped [15].

The variation of groundwater level for the whole research period under has been presented in Table 1., according to the reports of engineering geological surveys on the sites of various objects construction, which were provided by Ukrainian Main Industrial Research Institute of Engineering and Environmental Research (UkrNIIINTIZ) in the period from 1980 to 2014 [11-16].

Table 1. Groundwater level and precipitation changing from 1980 to 2014.

Object address	Conducting surveys year	Average annual Groundwater levels, m	Total precipitation for the year, mm
Quarter is limited by Klochkivska str., Borodinivska str., Khersonska str., per. Dosvidniy	1980	1,1 – 2,5	617
Klochkivska str., 99	1987	1,0	451
Klochkivska str., 101	2004	0,7 – 3,0	599
Angle of Khersonska str. and Klochkivska str.	2006	До 4,0	451

Sukhumska str.	2008	2,0 – 4,7	416
Klochkivska str., 117	2014	2,55 – 4,3	491

Source: [11-16].

The analysis of available engineering surveys for various years data [11-16] allowed to create a general review of the building development on the Klochkivska street site in the Kharkiv city, flood spreading and its influence to building structures, give a detailed description of the research area.

Many authors and organizations are dedicated researches for risks assessment of groundwater flooding [17-21]. The flooding risks in these surveys are estimated, as a rule, for urban areas in cases of leakage from utility networks.

2.1. Mathematical Modeling the Risk of Material Losses from Flooding

The research area of urban territory was recently built up by a multistory residential block, and practically the whole free area was covered with artificial cover - asphalt, which led to a significant decrease of the soil moisture evaporation and transpiration by vegetation [22]. The water balance of groundwater in this territory was violated, the atmospheric groundwater replenishment without a distinct position of evapotranspiration led to the rise of groundwater levels and flooding. It is advisable to perform a surface runoff volume calculation, and use these data in subsequent calculations to take into account the maximum potential impact of surface runoff on the groundwater replenishment.

Calculation of the Surface Runoff Volume

Surface runoff from the territory of cities and industrial sites is a significant source of pollution and clogging of water objects. The control over the discharging of contaminated surface runoff is regulated by the State Standard of Ukraine 3013-95 "Control rules for the rain and snow waste water allocation from the cities territory and industrial enterprises".

Surface runoff includes rain, snow, and water jet sewage.

The main sources of pollution on the site territory are:

- rubbish from the covers surface;
- products of road coverings destruction;
- emission of pollutants into the atmosphere from motor vehicles;
- streams of petroleum products on the covers surface;
- sites for collecting household rubbish.

The runoff coefficient value for the catchment basin calculates as average for the whole area by the formula:

$$\psi = \sum \alpha_i \cdot \psi_i , \qquad (1)$$

Where α_i – weight coefficients, equal in magnitude relative to the area occupied by this type of coverage, to the total catchment area, have been given in Table 2;

ψ_i - flow rates for different types of coatings have been given in Table 2.

Table 2. The weight coefficients values of different coatings types presented on the investigated area

№ n/p	Territory type	Area, hectares	Weight coefficient, a_i
1	Improved covers (asphalt)	1,2	0,1106
2	Constructed territories	8,5	0,7834
3	Green plantations	0,7	0,0645
	Unbuilt territory	0,45	0,0415
	Total:	10,85	

Source: [23]

Value of runoff factors are in table 3.

Table 3. Value of runoff factors

№	Type of drainage surface	The runoff factor value	
		Rain drain	Thawing drain
1	Improved covers (asphalt)	0,8	0,95
2	Constructed territories	0,6	0,6
3	Green plantations	0,1	0,2
4	Unbuilt territory	0,3	0,6

Source: [23]

The rain or thawing drain for year is calculated by the formula:

$$W = 10\cdot\psi\cdot F\cdot H \qquad (2)$$

where ψ – rain or thawing drain coefficient;

F – drainage surface area, hectares;

H – the precipitation layer for the warm or cold period of the year respectively. For calculations we accept the average data for Kharkiv - for the warm period of the year is H_r= 355 mm, for the warm period of the year is H_t = 170 mm.

Rain water volume:

ψ_r = 0,1106·0,8 + 0,7834·0,6+0,0645·0,1+0,0415·0,3 = 0,5774

W_r = 10·0,5774·10,85·352 = 22052,1 m^3/ year.

Thawed waters volume:

ψ_t = 0,1106·0,95 + 0,7834·0,6+0,0645·0,2+0,0415·0,6 = 0,6129

W_t = 10·0,6129·10,85·170 = 11304,9 m^3/ year.

The watering volume determines by the formula:

$$W_{sw} = 10\cdot m\cdot k\cdot F_m\cdot\psi \qquad (3)$$

where m – water consumption per unit area sink, l/m^2; k – number of sinks per year; F_m – processed coverage area, hectares; ψ –drain sewage watering coefficient.

We accept: m = 1,5 l/m^2; k = 100; ψ = 0,6.

Therefore:

W_{sw} = 10·1,5·100·1,2·0,6 = 1080 m^3/ year

The total volume of surface runoff waters from the catchment area for the year has been defined as the sum of the components:

$$W_{total} = W_r + W_t+W_{sw} \qquad (4)$$

W_{total}= 34437 m^3/ year

2.2. Input Model Data

1) Research area square: S = 0,1085 km^2.
2) The border length: L_t = 0,28+0,4+0,35+0,3 = 1,33 km.
3) Average baseline depth of groundwater level at the site: h_{ave} = 2,9 m.
4) Rain and thawing drain volume: W = 34437 m^3/ year.

To determine the risk of specific loss per unit area the formula (5) has been used for calculations.

$$R_f(A) = V_nP(V_n)P(L)L_t, \qquad (5)$$
$$R_{sf}(A) = R_f(A)/S,$$

where V_n – linear speed of process development, m / year, $P(V_n)$ – realization probability of this speed, $P(L) = V_n(A) = L_n/L_t$ – geometric probability of linear defeat (vulnerability) of the territory at the length of the development process boundary L_n and its total length L_t , S– square of the estimated coastal area, m^2, hectares.

To use formula (5) we need to find the linear velocity of the flooding process. We have a formula for its definition:

$$V_n(A) = \frac{L_n}{L_t}, \qquad (6)$$

which characterizes the geometric probability. L_t – the perimeter of the entire territory, L_t=1,33 km. L_n – this is the length of the flood development border.

In this case (the most significant) for flooding, the development border coincides with the entire length, that is $L_n = L_t$, that's why $V_n(A) = 1$.

Let's accept that $P(V_n)$=1 km/year, that is the most dangerous case.
So $R_f(A)$ = 1,33 km^2/year.
The risk per unit of time will be measured in km^2/km^2 per year.
For the second of the formulas (5) we have:

$$R_{s\,f}(A) = \frac{1{,}33}{0{,}1085} = 12{,}26 \text{ km}^2/\text{km}^2 \text{ per year.}$$

Thus, the risk of material losses from flooding of the entire study area is 12,26% per year.

2.3. Calculation of the Flood Spread Rate at the Investigated Site

It has been taken for the techno-natural process:
$P(h) = P(V_n) \neq 1$.
The value $P(h)$ calculates by formula:

$$P(h) = \sum_{i=1}^{n} P\left(\frac{h}{w_i}\right) \cdot P(w_i), \qquad (7)$$

$n=1$, raising level probability h_{cp}=2,9 m per year, on condition, that W - volume of rain and thawing runoff, W=34437m^3/year.
$V=L_t \cdot h_{cp}$,

where V – estimated volume.

h_{cp} - average output level of groundwater in the site, h_{cp}=2,9 m, L_t - border length, L_t=1,33km=1330m.

$V+W=L_\kappa h_\kappa$,
L_κ – the finite extent of the border, m.

h_κ – the final groundwater level, which is the limit, where flooding begins, according to the standard [24] h_κ=2,5m.

$L_t \cdot h_{cp}+W=L_\kappa \cdot 2{,}5$
Hence:
$1330 \cdot 2{,}9+34437 = L_\kappa \cdot 2{,}5$
L_κ = 15317,6 m.

3. RESULTS AND DISCUSSION

The rate of flood spreading per year for the research plot has been found: V_n = (15317,6-1330)/365 = 38,3 m/year.

According to calculations, the due length of the flooded area will increase by 9.5 m annually. And the area of flooding will increase on 90 m^2. Based on the total area of research area, which is equal to S = 0,1085 km^2, the flooding area will increase on 1% per year.

4. CONCLUSION

The influence of construction development on the groundwater level increase has been evaluated. The analysis of available data of engineering surveys for different years has been conducted. It allowed to create a general situation of the construction development at the site on the Klochkivska street in the

Kharkiv city, flood spreading and its influence on building structures, gave a detailed description of research area.

The mathematical modeling of the material losses risk from flooding has been provided in the paper. The risk of material losses from flooding on the entire research area is 12,26% per year.

On the basis of the Belousova A.P. mathematical model [7], the new parameter has been taken into account - the surface runoff volume. The rate of flood phenomena spreading per year for research territory has been calculated, which expresses in the flooded area perimeter increasing for about 38,3 m/year, and the flooding area increases on 90 m^2, or 1% per year.

In view of the new construction development in Kharkiv and the concerned floodplain area spreading, it will be proper to equip the observation wells network. This will allow to obtaining actual data as the basis for the flood spreading forecast and for measures to prevent this phenomenon.

REFERENCES

[1] E. Serikova, E. Strelnikova, and V. Yakovlev, "Additional groundwater replenishment in the large cities of Ukraine on the Kharkiv city example," *Urban Management of Cities*, vol. 130, pp. 13-18, 2016.

[2] S. I. Primushko, G. D. Biloshapska, and V. F. Velichko, *Information yearbook concerning to the activation of the dangerous exogenic geological processes on the territory of Ukraine according to the monitoring of EGP. Ministry of the Environment of Ukraine, State geological department, Sate information geological fond of Ukraine. Ch. ed.* vol. 7, 2010.

[3] S. I. Primushko, G. D. Biloshapska, and V. F. Velichko, *Information yearbook concerning to the activation of the dangerous exogenic geological processes on the territory of Ukraine according to the monitoring of EGP. Ministry of the Environment of Ukraine, State geological department, Sate information geological fond of Ukraine. Ch. ed.* vol. 11, 2014.

[4] S. I. Primushko, G. D. Biloshapska, and V. V. F., *Information yearbook concerning to the activation of the dangerous exogenic geological processes on the territory of Ukraine according to the monitoring of EGP. Ministry of the Environment of Ukraine, State geological department, Sate information geological fond of Ukraine. Ch. ed* vol. 15, 2018.

[5] E. N. Serikova, E. A. Strelnikova, V. V. Yakovlev, L. Y. Anishenko, and L. A. Pisnya, "Evaluation of the adequacy of proposed prediction mathematical model on the actual data of groundwater level monitoring in the central part of Kharkiv city," *Scientific Journal*, vol. 11, pp. 43-47, 2017.

[6] S. K. Abramov, E. S. Dzektser, and Z. P. Gavshina, "Flooding factors of industrial enterprises and measures to combat them," *Industrial Engineering*, vol. 1, pp. 21-32, 1971.

[7] A. P. Belousova, "Risk flooding assessment of territories by groundwater during floods," *Water Resources*, vol. 38, pp. 30-38, 2011.

[8] E. S. Dzektser and M. V. Bolgov, "Stochastic regularities of flooding of the built-up areas by groundwater," *Geoecology*, vol. 4, pp. 104-117, 1995.

[9] V. S. Kremez, "Actual issues of flooding modeling of territories and other hazardous processes associated with changes in the groundwater regime," *Ecology of Safety and Security of Life*, vol. 6, pp. 56-64, 2003.

[10] Y. O. Yakovlev, A. V. Lushchik, and M. I. Shvirlo, "Major changes in engineering-geological conditions within flooded territories and directions of their study," *Environmental Ecology and Life Safety*, vol. 6, pp. 28-32, 2003.

[11] V. G. Chunikhin and V. G. Babayev, "Technical report of engineering geological surveys on the territory of the block construction on the Klochkivska street in the Kharkiv city. Ukrainian Main Industrial Research Institute of Engineering and Environmental Research (UkrNIIINTIZ). Kharkiv," p. 116, 1980.

[12] V. G. Chunikhin and V. A. Sokolov, "Report of engineering geological surveys at the construction site of the main academic module of the Sports Faculty of the Kharkiv State Academy of Physical Culture. Ukrainian Main Industrial Research Institute of Engineering and Environmental Research (UkrNIIINTIZ)," p. 53, 1987.

[13] V. A. Sokolov and Y. B. Lisychenko, "Report of engineering geological surveys on the plot of a projected residential building at Klochkivska street, 101 in Kharkiv. Ukrainian Main Industrial Research Institute of Engineering and Environmental Research (UkrNIIINTIZ). Kharkiv," p. 52, 2004.

[14] G. G. Strizelchik and I. A. Zakopaylo, "Scientific and technical report of engineering geological surveys at the site of construction of the offices complex with auxiliary premises on the

Klochkivska street, corner of Khersonskaya street in Kharkiv. Ukrainian Main Industrial Research Institute of Engineering and Environmental Research (UkrNIIINTIZ). Kharkiv," p. 48, 2006.

[15] Y. B. Lisichenko and A. I. Pogrebnyak, "Technical report of engineering geological surveys on the plot of construction of a residential complex Klochkivska street, 117 in Kharkiv (Project stage). Ukrainian Main Industrial Research Institute of Engineering and Environmental Research (UkrNIIINTIZ). Kharkiv," p. 45, 2014.

[16] Y. B. Lisychenko and N. A. Dolgopolov, "Report on engineering geological surveys at the construction site of multi-storey residential buildings on the street. Sukhumskaya in Kharkiv. Ukrainian Main Industrial Research Institute of Engineering and Environmental Research (UkrNIIINTIZ). Kharkiv," p. 48, 2008.

[17] N. P. Kuranov and P. N. Kuranov, "Koroteev D.G. Methodology and Methods of Calculating the Drainage Rate at Engineering Protection from Underflooding of Local Objects," in *Proceedings of Moscow State University of Civil Engineering*, 2015, pp. 138-152.

[18] V. I. Osipov, "Assessment and Management of Natural Risks. Proc. of Practical Conf," in *Emergency Risk Management". Moskow.*, 2001, pp. 34-45.

[19] A. L. Rogozin, "The current state and perspectives of the natural risks assessment and management in building. Analysis and assessment of natural and technogenic risk in construction. Moskow," pp. 7-25, 1995.

[20] V. T. Alymov and N. P. Tarasova, "Technogenic risk. Analysis and evaluation. A manual for schools. Moskow. "Academkniga"," p. 118, 2004.

[21] A. M. Protsenko, N. A. Makhutov, and A. E. Artemyev, "Safety of the population and the environment of Moscow: research and management problems. Problems of safety in emergency situations," *Moskow*, vol. 2, pp. 75-86, 1997.

[22] E. Serikova, E. Strelnikova, and V. Yakovlev, "Mathematical model of dangerous changing the groundwater level in Ukrainian industrial cities," *Journal of Environment Protection and Sustainable Development*, vol. 1, pp. 86-90, 2015.

[23] City ecology, "Ed. Stolberg V. F. Kiev. Libra," p. 464, 2000.

[24] Y. Chervinsky, V. Shuminsky, Y. Slusarenko, V. Tarasuk, and D. Dmitriev, "State building regulations of Ukraine. Protection from dangerous geological processes. Main design points. DBN V.1.-2009," p. 91, 2010.