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EXPERIMENTAL SUBSTANTIATION OF THE NPEMFE GEOPHYSICAL METHOD TO SOLVE ENGINEERING AND GEOLOGICAL PROBLEMS

І. В. Чушкіна, Д. С. Пікареня, О. В. Орлінська, Н. М. Максимова. ЕКСПЕРИМЕНТАЛЬНЕ ОБҐРУНТУВАННЯ ГЕОФІЗИЧНОГО МЕТОДУ ПІЕМПЗ ДЛЯ ВИРІШЕННЯ ІНЖЕНЕРНО-ГЕОЛОГІЧНИХ ЗАДАЧ. *В наш час діагностування технічного стану гідротехнічних споруд (ГТС),водогосподарського комплексу також як і локалізації ділянок, які потребують першочергового ремонту, є досить актуальними науково-практичними задачами. Багаторічні польові дослідження показали високу ефективність застосування геофізичного методу природного імпульсного електромагнітного поля Землі (ПІЕМПЗ) для виявлення зон підвищеної фільтрації і порушень в тілі ґрунтових ГТС. Вперше були проведені лабораторні дослідження для аналізу характеру генерації електромагнітного випромінювання (ЕМВ) в зразках пухких ґрунтів під час їх навантажень, щоб експериментально обґрунтувати можливість використання швидкого і маловитратного (за часом та фінансами) методу ПІЕМПЗ для діагностування технічного стану ґрунтових ГТС водогосподарського призначення. Результати експериментальних досліджень дозволили встановити основні закономірності розвитку коливань ЕМВ в ґрунтовій товщі під час її стиснення та обводнення, що пояснює можливість визначення зон фільтрації та замочування в тілі ґрунтових ГТС. Ефективність застосування геофізичного методу ПІЕМПЗ розглянута на прикладі регулюючого басейна (РБ) Калинівської зрошувальної системи, розташованого в Синельниківському районі Дніпропетровської області. Дослідження технічного стану регулюючого басейну проведено в комплексі з «кількісним» методом вертикального електричного зондування, який доповнив дані зйомки ПІЕМПЗ. Достовірність результатів зйомки підтверджується збіжністю рисунка поля ПІЕМПЗ, отриманого в результаті моніторингу РБ в 2013 р. і 2017 р. Економічна доцільність впровадження не руйнуючого методу для діагностики технічного стану гідротехнічних споруд зрошувальних систем підкреслюється необхідністю покращення еколого-меліоративного стану прилеглих територій.*

Ключові слова: *метод природного імпульсного електромагнітного поля Землі, метод вертикального електричного зондування, одометр, пухкі породи, електромагнітне випромінювання, ґрунтові гідротехнічні споруди, діагностика технічного стану*

И. В. Чушкина, Д. С. Пикареня, О. В. Орлинская, Н. Н. Максимова. ЭКСПЕРИМЕНТАЛЬНОЕ ОБОСНОВАНИЕ ГЕОФИЗИЧЕСКОГО МЕТОДА ЕИЭМПЗ ДЛЯ РЕШЕНИЯ ИНЖЕНЕРНО-ГЕОЛОГИЧЕСКИХ ЗАДАЧ. *В настоящее время диагностика технического состояния грунтовых гидротехнических сооружений (ГТС), также как и локализация участков, требующих первоочередного ремонта, и снижение фильтрационных потерь оросительной воды, являются достаточно актуальными научными и практическими задачами. Многолетние полевые исследования показали высокую эффективность применения геофизического метода естественного импульсного электромагнитного поля Земли (ЕИЭМПЗ) для обнаружения зон повышенной фильтрации и нарушения сложения в теле грунтовых ГТС. Впервые были проведены лабораторные исследования для анализа характера генерации электромагнитного излучения (ЭМИ) в образцах рыхлых грунтов при их нагрузке, чтобы экспериментально обосновать возможность использования быстрого и недорогого (с точки зрения времени и финансов) метода ЕИЭМПЗ для диагностики технического состояния грунтовых ГТС сельскохозяйственного назначения. Результаты экспериментальных исследований позволили определить основные закономерности развития колебаний ЭМИ в грунтовой толще при её сжатии и обводнении, что объясняет возможность определения зон фильтрации и обводнения в теле грунтовых ГТС. Эффективность применения геофизического метода ЕИЭМПЗ рассмотрена на примере регулирующего бассейна (РБ) Калиновской оросительной системы (ОС), исследование технического состояния которого было проведено в комплексе с «количественным» методом вертикального электрического зондирования (ВЭЗ), дополняющего данные съемки ЕИЭМПЗ. Достоверность результатов съемки методом подтверждается схожестью рисунка поля ЕИЭМПЗ, полученного в результате мониторинга состояния РБ в 2013 и 2017 годах. Экономическая целесообразность внедрения не разрушающих методов для диагностики технического состояния гидротехнических сооружений оросительных систем подчеркивается необходимостью улучшения эколого-мелиоративного состояния прилегающих территорий.*

Ключевые слова: *метод естественного импульсного электромагнитного поля Земли, метод вертикального электрического зондирования, одометр, рыхлые породы, электромагнитное излучение, грунтовые гидротехнические сооружения, диагностика технического состояния.*

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Statement of the problem. Majority of the earth hydroengineering structures (HES) of hydroeconomic purpose were built in the middle of the last century; the structures belong to CC1 structure category. Nowadays, most of those structures are at the end of their resources due to considerable technical wear. That has resulted in deterioration of their technical conditions and decreased level of their safe operation. Almost all old-design hydroengineering structures need maintenance operations. They are impossible to be repaired simultaneously; thus, it is necessary to implement a complex of diagnostic tests to specify the HES requiring priority repair. Currently, technical condition of those structures as well as their meeting the safety requirements are evaluated mostly visually, making it possible to identify only certain sites of damaged plates of face lining and filtration-proof membrane. That also concerns the components of agricultural irrigation networks – retention basins (RB) and principal channels (PC) surrounded by the earth dams. Hidden filtration zones within the dams may be found by using control and measuring equipment or remote sensing methods.

According to the recommendations of normative documents, it is proposed to determine zones of increased filtration within the earth dam body, protective dams, and reservoir beds using a system of geophysical methods including the following ones: vertical electric sounding (VES), microelectric sounding (MES), electric profiling (EP), and method of natural electric fields (NEF) [1].

Unfortunately, those methods are considered to be rather time- and labour-consuming. That highlights the topicality of developing and implementing the innovative methods for complex evaluation of technical condition and detection of hidden filtration zones within the bodies of earth HESs; that will help localize and maintain timely the specified site making it possible to prolong operation period of the object and prevent rise of ground water level within the neighbouring territories.

During the recent 10 years, Dnipro State Agrarian and Economic University (DSAEU) and Dniprovsky State Technical University (DSTU) have been applying a method of natural pulse electromagnetic field of Earth (NPEMFE), developed in the 1980s, to determine hidden zones of filtration, watering, and suffusion development within the HES dams [2-6]. Traditionally, that method is used to prospect ore deposits and ground water, to evaluate slides and other phenomena [2, 8-2], and to perform quick examination of HES technical condition; moreover, the technique is of low estimated cost. Its main disadvantages are as follows: lack of theoretical and experimental substantiation and, as a result, impossibility to carve up the section and define the depth down to the anomaly object. The NIEFF method has been substantiated experimentally for the cases of mineral deposit prospecting as well as solving engineering and geological problems within the crystalline and sedimentary consolidated rock; in terms of man-made loose soils, electromagnetic radiation (EMR) has not been studied yet [7, 11-21, 25].

Analysis of recent studies and publications. As a rule, generation of electromagnetic radiation was analyzed during deformation of crystalline or consolidated sedimentary rocks as well as artificial building materials. Such issued were considered by Vorobiov, O.A., Salnikov, V.N., Gold, R.M., Bespalko, A.A., Yavorovich, L.V., Salomatin, V.N., Zashchinsky, L.A., Vyshnevsky, N.L., Bulat, A.F., Prykhodchenko, V.L., Soboliev, G.A., Kurlenia, M.V., Yakovytska, G.Ye., Malyshkov, S.Yu., Yegorov, P.V., Alekseiev, D.V., Kolpakova, L.A., Goncharov, A.I., Trubetsky, K.N., Viktorov, S.D., Osokin, A.A., Shliapin, A.V., Yeremenko, A.A., Shtyrts, V.A., Zang, A., Stenberg, L., Specht, S., Milkereit, C., Schill, E., Kwiatek, G., Dresen, G., Zimmermann, G., Dahm, T., Weber, M., Cornet, F.H., Hagag, W., Obermeyer, H., Naoi, M., Rubinstein, J.L., Mahani, A.B., Sedlak, P., Sikula, J., Lokajicek, T., Mori, Y., Balageas, D., Maldague, X., Burleigh, D., Vavilov, V.P., Oswald-Tranta, B., Roche, J.M., Carlomagno, G.M., Vavilov ,V., Świderski, W., Derusova, D., and others [2,7,10-31].

Papers [28-30] analyzed qualitative contribution of electromagnetic signal intensity with energy properties of solid bodies. It has been defined that the intensity of electromagnetic signal grows along with the increase in mechanical and electric density of solid bodies [11]. Studies [32] proposed the approach based on the measured minor flows within the loaded rocks to determine their integrity.

Studies by Bespalko, A.A. and Yavorovych, L.V. [11] dealing with EMR during dynamic effect of sandstone samples in terms of their different water-saturation and changes in the solution mineralization (Fig.1) are of special interest. When sandstone is held in the distilled water that results in considerable decrease in EMR amplitude comparing with the sample in its initial state. Saturation of distilled water with NaCl is accompanied by the increasing EMR amplitude. In this context, EMR of porous sandstone of different water-saturation degree is proportional to the effecting energy.

Singling out previously unsolved parts of the general problem. Problems concerning the nature of EMR occurrence in loose rock, e.g. argillaceous, loamy, and sandy soils, which usually makes up the HES body of CC1 structure category in terms of irrigation systems, reservoirs, and tailing facilities, have not been studied before.

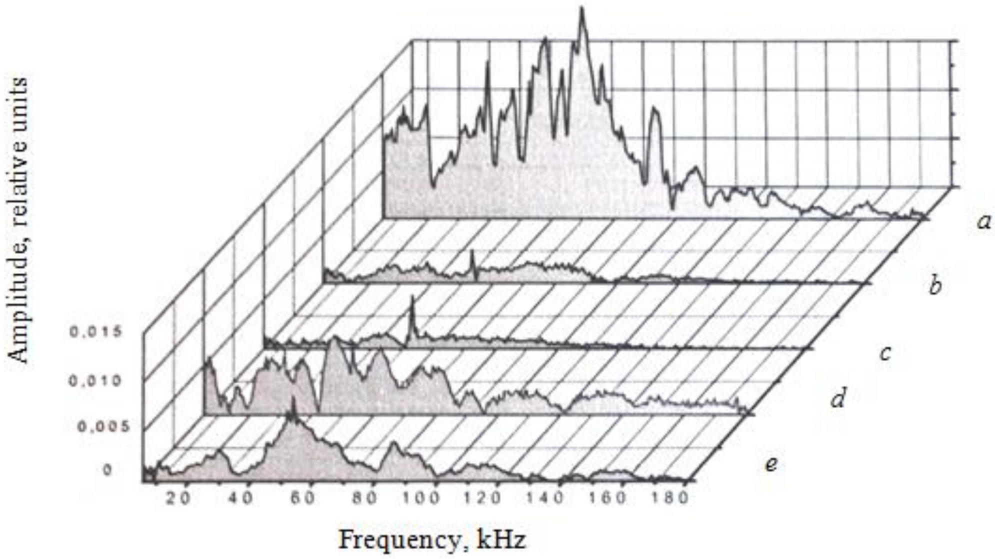


Fig. 1. Amplitude-frequency spectra of electromagnetic signals in terms of acoustic excitation of sandstone samples [11]: *a* – in the initial sample state; *b* – within the samples held in distilled water during 24 hours; *c* – in NaCl water solution with the concentration of 1%; *d* – 2.5%; *e* – 3.75%

Formulation of the paper objective. Objective is to substantiate experimentally application of the NPEMFE method within the man-made ground and evaluate its possibility for determining hidden filtration zones in terms of agricultural HES.

Description of the research methodology (structure, sequence). To analyze interaction between the changes in electromagnetic radiation (EMR) amplitude occurring within the man-made earth dams of retention basins during their filling-emptying, a series of experiments has been carried out involving compression of man-made ground samples on the odometer within simultaneous record of density of EMR pulse flow being generated during the loading.

Physical characteristics of soils (humidity, density and solid phase, porosity and porosity coefficient) were determined according to standard methodologies [33].

During the first series of experiments, loading values of ground samples on the odometer were selected basing upon the real loads in the retention basin filled with water completely up to the level of 4.2 m. According to the calculations, water pressure is 42.2 kPa; taking into consideration pressure of concrete plates, overall loading value is specified as 45.3 kPa.

Second series of experiments meant studies in terms of RB emptying before winter time. When water was discharged from the basin, 0.4-0.5 m layer of water was left in the basin forming pressure of 5.3 kPa along with the plates. Those experiments were carried out to study EMR level during relaxation of natural soils.

The experiments have resulted in the construction of graphs of dependences of EMR pulse flows upon the loading degree of the ground samples. To validate the NPEMFE method application, monitoring studies have been performed in terms of retention basin of Kalynivska irrigation system (IS) in 2013 and 2017. To determine the ground water level (GWL), method of vertical electric sounding was applied along with the NPEMFE method.

Statement of the basic research material. Retention basins and bund walls are built from the native ground represented by loessoid varieties. According to the majority of inter-regional water economy authorities, the dams are constructed using heavy clay loams or sand loams. Ground samples taken from the dams and near basins belong to clay loams and sandy loams. Basing on the proper studies by the picnometer method, average density of sandy loam soil is 2.74 g/cm^3; in terms of plasticity and flow values, they belong to plastic varieties (Ip = 1.8-2.5; I_L = 0.5); as for granulometric composition, they belong to dusty soils as they are characterized by following granulometric composition (in terms of fraction fineness mass): 0.5-1 mm – 0.07 %; 0.25-0.5 mm – 0.61 %; 0.1-0.25 mm – 61.25 %; >0.1 mm – 38.07 %. Average natural moisture is 8.63 %.

Density of the clay soil particles is 2.75 g/cm^3; in terms of plasticity and flow value, they belong to light (Ip = 17,51-18,32), solid (I_L = -(0.23-0.18)) type; content of sandy particles is 0.02 % which also indicates some varieties [36]. Natural moisture of clays is 19.3 %.

Table 1 represents results of compression tests on the odometer.

Along with the compression studies, pulses of electromagnetic radiation were registered according to the scheme represented in Fig. 2.

Let's consider the results of the effect of soil compression upon the changes in pulse electromagnetic radiation. Figures 3-11 show compression curves ε = f (t) combined with the density of EMR pulse flow (pulse/second). Periods of EMR rise and drop during the experimental studies are marked with red straight lines, which coincide conditionally with the results of EMR curve smoothing by means of polynomial approximation. Curves of the trend represented in blue are constructed with the help of Microsoft Excel; they are described by the sextic equation.

Thus, in terms of maximum loads (45.58 kPa) corresponding to the conditions of a water-filled retention basin, wavelike alternation of ranges of EMR pulse numbers with their repeated excitation has been obtained (Fig. 3-5). That is traced properly beginning from 1320 s since the start of experiment #1 (Fig. 3), from 1380 s – for the experiment #2 (Fig. 4), and in terms of the experiment #3 – from 1200 s since the third loading stage or from 4680 s since the beginning of the study (Fig. 5).

Table 1

Initial data and experimental results

Experiment number	Maximum pressure, kPa (number of loading degree)	Soil type (backfilling height, mm)	Soil density before compression, g/cm^3	Soil density after compression, g/cm^3	Relative compression	Loading period, s (hour)
1	45.58 (1)	sandy loam with natural moisture (24 mm)	1.61	1.99	0.015	2700 (0.75)
2	45.58 (1)	sandy loam with natural moisture (24 mm)	1.64	2.06	0.087	2820 (0.78)
3	45.58 (3 degrees: 16.3, 16.3, 13.0 kPa)	sandy loam with natural moisture (24 mm)	1.64	2.04	0.073	5460 (1.5)
4	5.3 (1)	sandy loam with natural moisture (24 mm)	1.68	2.34	0.038	2520 (0.7)
5	5.3 (1)	sandy loam with natural moisture (24 mm)	1.64	1.95	0.041	2580 (0.72)
6	5.3 (1 degree)	sandy loam with natural moisture (24 mm)	1.69	2.01	0.015	2827 (0.79)
7	5.3 (1)	sandy loam with additional moistening (9 mm)	1.65	1.99	0.0129	2760 (0.77)
8	5.3 (1)	sandy loam with additional moistening (12 mm)	1.61	1.93	0.0199	2760 (0.77)
9	5.3 (2 degrees.65 kPa)	clay with natural moisture (24 mm)	1.65	1.96	0.011	120360 (33.43)
10	5.3 (4 × 1.325)	clay with natural moisture (24 mm)	1.71	2.38	0.025	533100 (148.08)

Note: additional moistening of sandy loams was applied to simulate watering process in case of filtration from the retention basin.

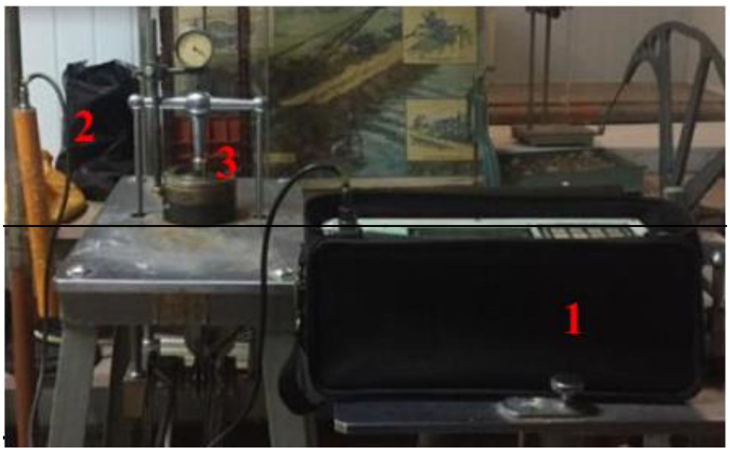


Fig. 2. Appearance of «МІЕМП-14/4» device 4 (*1*) with receiving antenna (*2*) during simultaneous EMR recording and loading of clay loam and sandy loam samples on the odometer (*3*)

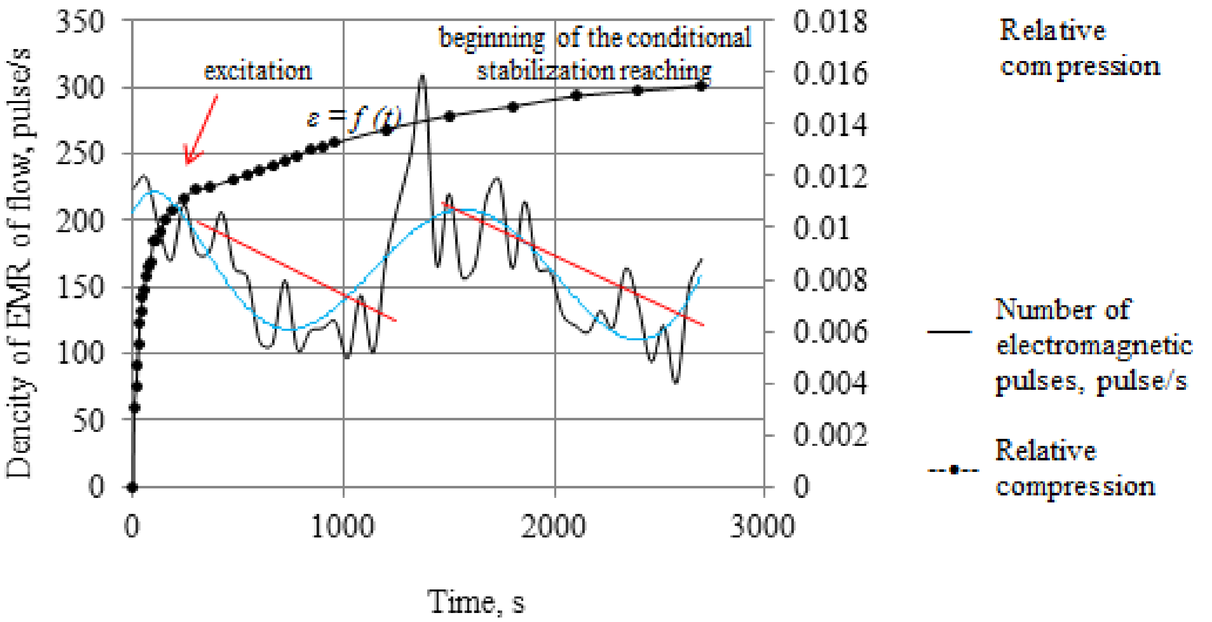


Fig. 3. Graph of EMR dependence upon sandy loam loading (Experiment #1)

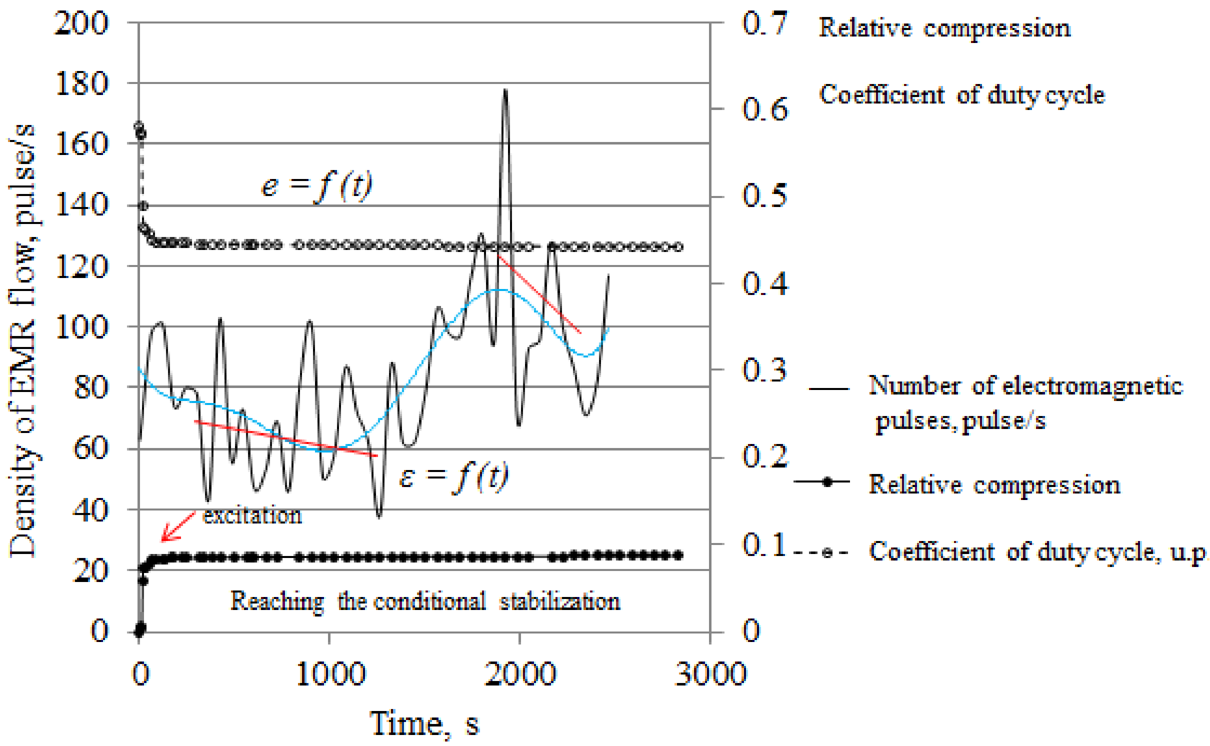


Fig. 4. Graph of EMR dependence upon sandy loam loading (Experiment #2)

Probably, first peak of the density of EMR pulse flow is stipulated by the closing of gaps and cavities in the soil sample in terms of loading increase. It is most likely that the drop of EMR curve is determined by the decrease in acoustic emission, which transfers partially into EMR. EMR growth (second maximum) may be connected with the deformation of crystals of argillaceous materials characterized by minor piezo-effect with following reorientation of crystals and their fragments into the plane perpendicular to the pressure (descending branch of graphs after the second maximum).

Further experiments were carried out with the decreased pressure (down to 5.3 kPa); that corresponds to the conditions of a retention basin, which is not completely emptied (Fig.6-8).

Fig. 9 and 10 show EMR generation during artificial additional moistening of sandy loam samples up to 24.7-25.4 % during the experiment in terms of the emptied retention basin; that simulates processes of watering due to filtration. It is clear that EMR curve has one excitation type at the beginning of compression; then, it experiences dramatic fall demonstrating flat lines. In this context, it should be noted that the more moistened the soil is, the more straight the line is (Fig.10). That is very important observation since it demonstrates that in terms of sandy loam watering, there is the absorption of EMR pulses being the basis to specify zones of watering and filtration with the help of the NPEMFE method.

Fig. 11 shows the nature of EMR changes during the argillaceous soil loading. In this context, EMR excitation in terms of the compression stabilization of a sample is observed.

Results of compressive studies have shown that the increased EMR values correspond to the maximally stressed state of the man-made ground and vice versa – their drop is peculiar for relaxation of the soil samples. Thus, extremes of the amplitude of EMR oscillation are recorded at the beginning of the compression experiments during the most intensive sample compression. The peak excitation is followed by slight "drop" in the pulse number with its further slow rising. That is stipulated by the decreased intensity in the process of soil compression. In terms of the watered soils, amplitude of EMR oscillation is insignificant owing to the moisture redistribution (experiments #7, 8).

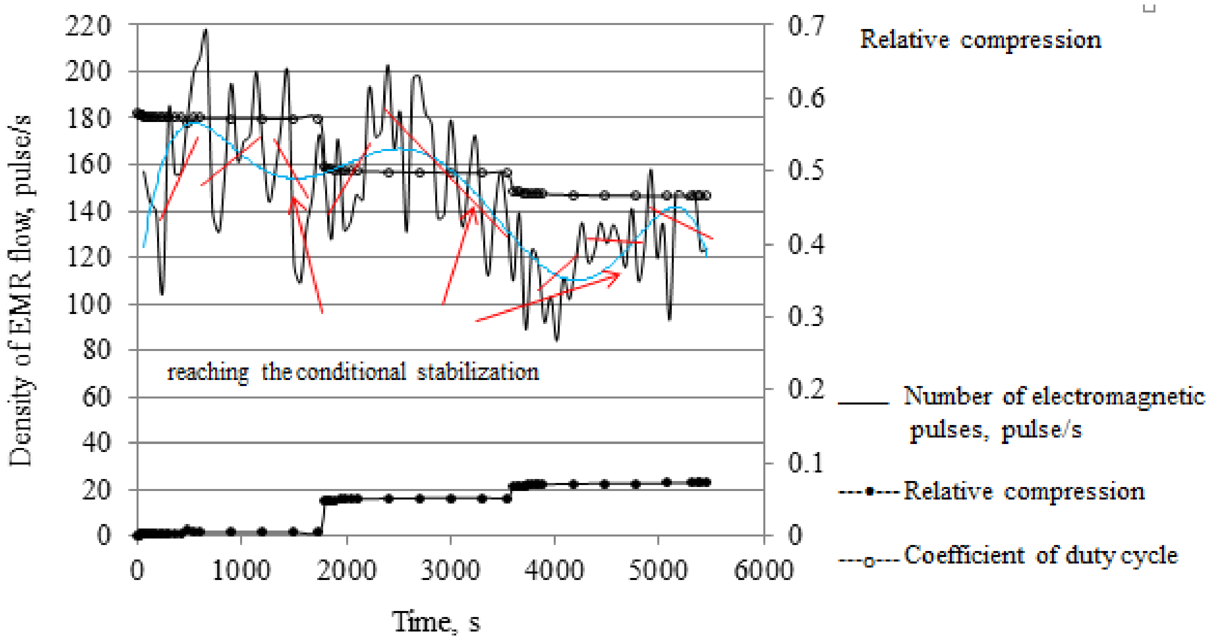


Fig. 5. Graph of EMR dependence upon sandy loam loading (Experiment #3)

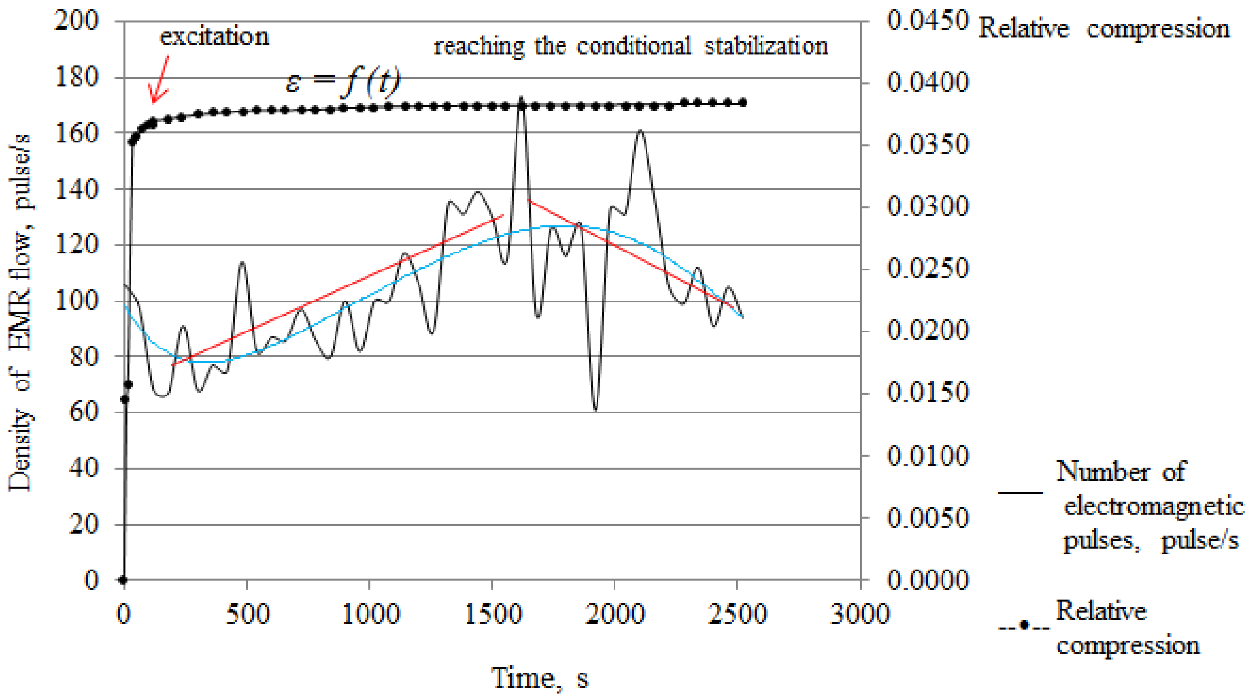


Fig. 6. Graph of EMR dependence upon sandy loam loading (Experiment #4)

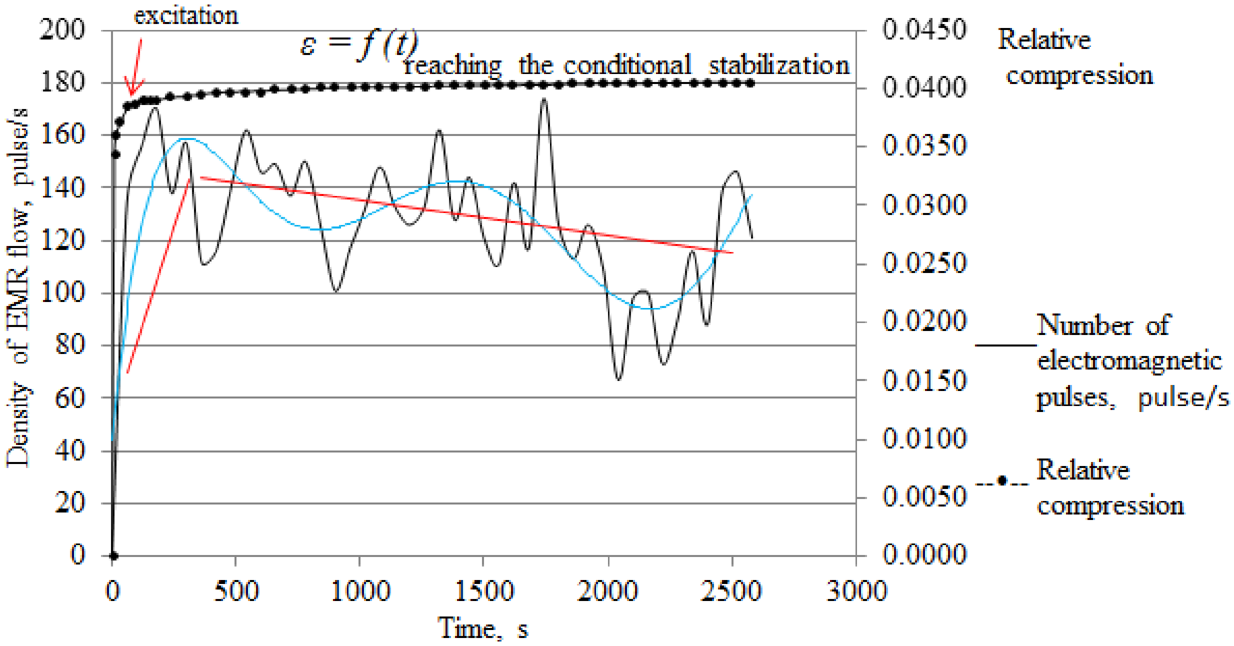


Fig. 7. Graph of EMR dependence upon sandy loam loading (Experiment #5)

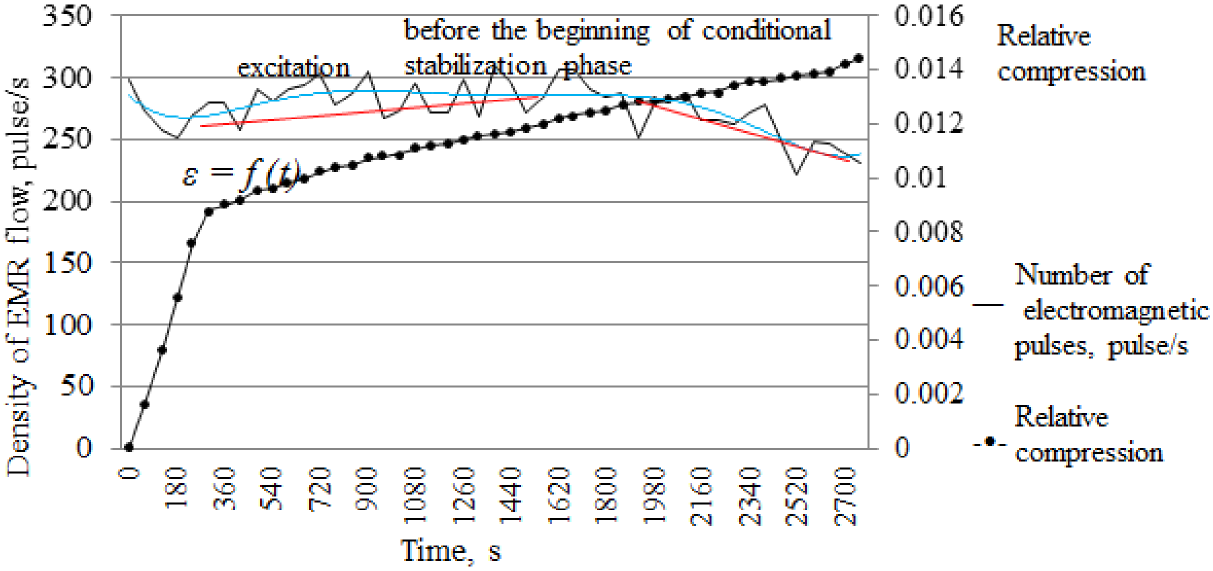


Fig. 8. Graph of EMR dependence upon sandy loam loading (Experiment #6)

Laboratory studies of the uniaxial compression of argillaceous soils on the odometer have helped determine the following.

1. Increasing pressure on the sample results in the development of electromagnetic signal similar in its characteristics to the signal received in terms of the loading, which effect the samples of crystalline and consolidated sedimentary rock.

2. For the first time, as a result of analysis of compression of sandy loam and clay samples on the odometer, it has been determined that increasing stress-strain state of the soils provoke gradual rise of the electromagnetic radiation amplitude (it is observed at the beginning of every loading stage).

3. Availability of electromagnetic radiation during the transfer of uniaxial loading on the argillaceous soil sample may be explained by the decrease in its porosity and occurrence of acoustic signal during the closing of pores, being characteristic for experiments # 4-10, taking into consideration transferred pressure p = 5.3 kPa onto the argillaceous soil samples, and at the beginning of experiments # 1-3, if p = 45.58 kPa.

4. It is proved experimentally that in terms of man-made ground moistening, EMR amplitude experience its decrease.

Thus, the specified regularities make it possible to substantiate experimentally possible application of the NPEMFE method to detect technical condition of the retention basins and principal channels by localizing zones of loosening and watering of the HES body; those zones are characterized by low

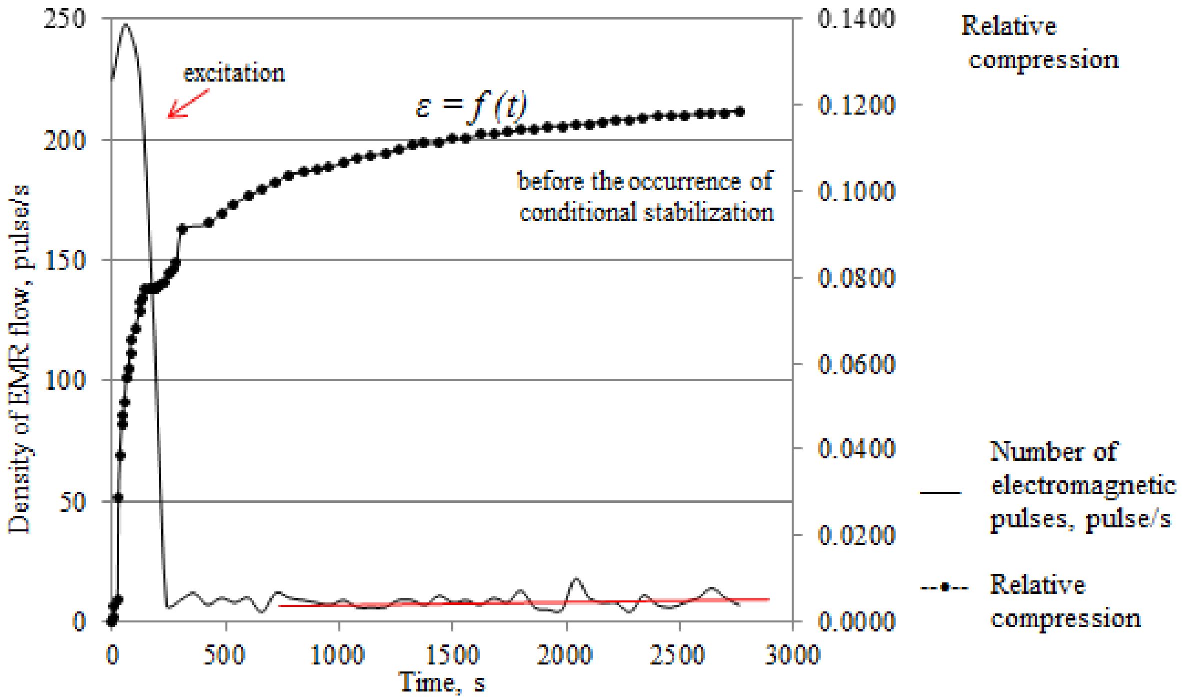


Fig. 9. Graph of EMR dependence upon sandy loam loading (Experiment #7), artificial moistening is 24.7 %

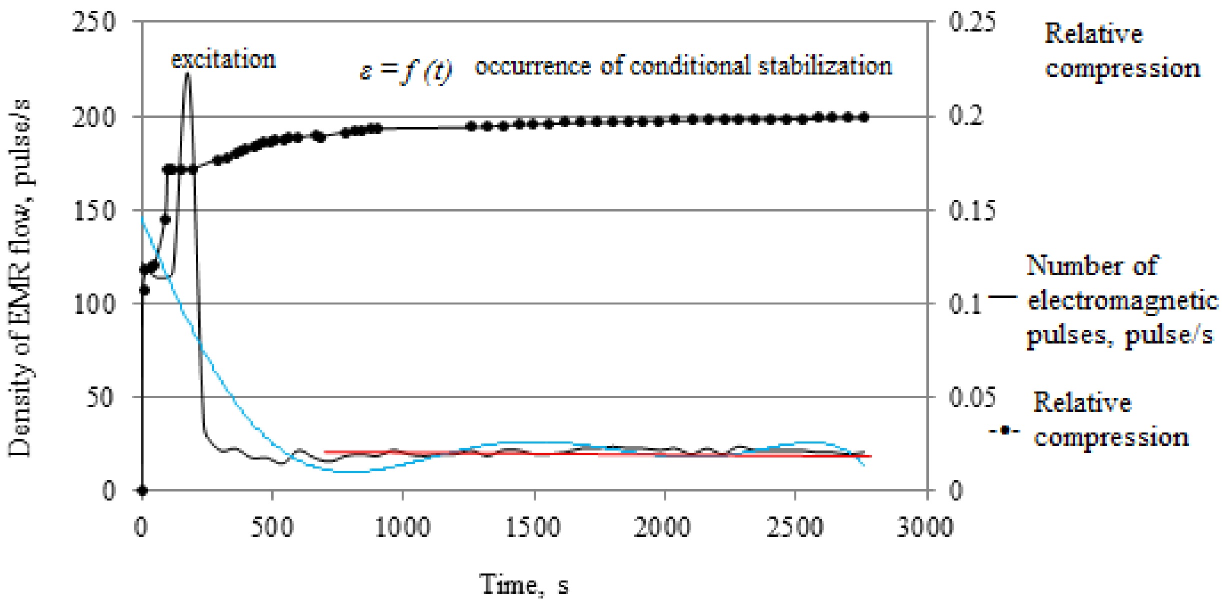


Fig. 10. Graph of EMR dependence upon sandy loam loading (Experiment #8), artificial moistening is 25.4 %

EMR values. Results of technical evaluation of the earth HESs, including agricultural ones, – 10 retention basins and 2 irrigation channels, are represented in detail in papers by the authors [2-6].

Consider the results of detecting hidden filtration zones within the HES body in terms of retention basin РБ-1 of Kalynivska irrigation system located in Sinelnikovo district of Dnipropetrovsk Region.

To validate the data obtained using the NPEMFE method, in spring 2013 and autumn 2017 technical conditions of RB of Kalynivska irrigation system were monitored in terms of its two states: before its filling with water and in when it was water-filled.

According to the data of field studies using *Golden Software Surfer 8* computer product, schematic maps of the density of pulse flow of the NIEFF magnetic component have been built (Fig. 12). The maps demonstrated the repeated nature of the results of field studies of 2013 and 2017. Interpretation of the field study results is based on the effect of intense absorption of the NPEMFE pulses by the considerably moistened rock or building materials.

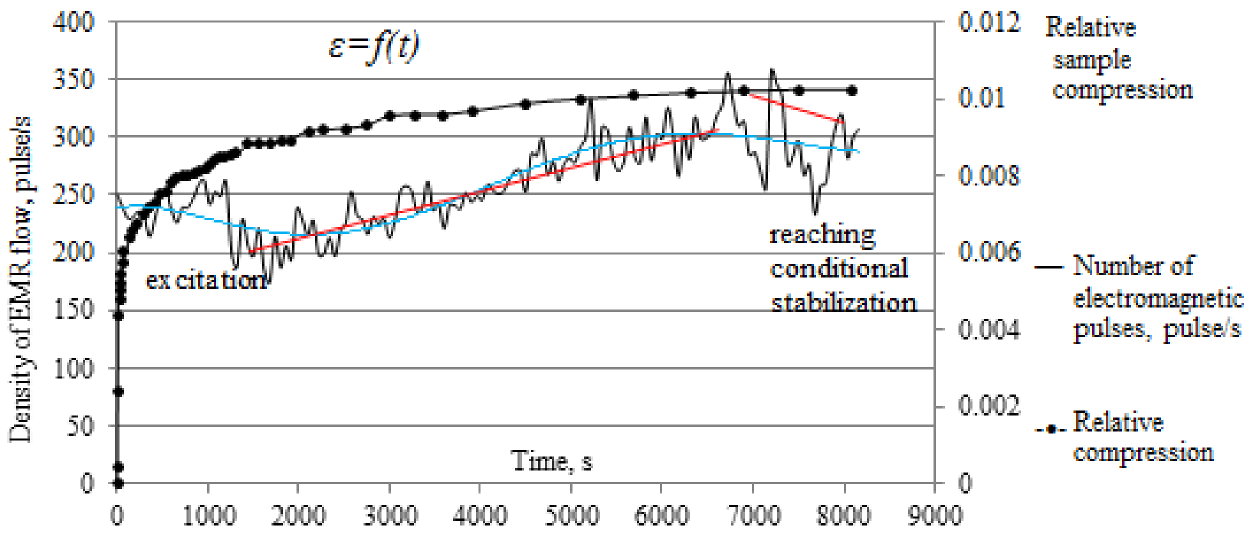
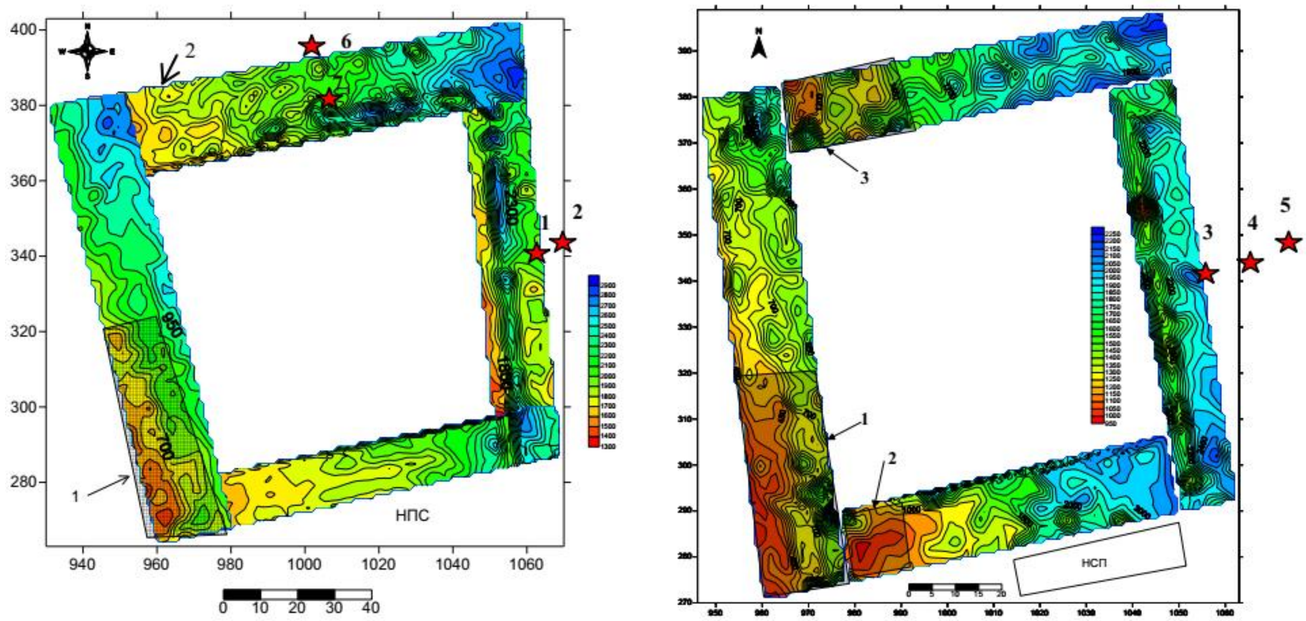


Fig. 11. Graph of EMR dependence upon clay loading (Experiment #9)

In terms of the schemes, sites of the decreased values of density of pulse flow of the NPEMFE magnetic component (red and yellow colours) correspond to the zones of EMR absorption; they are diagnosed as the sites of watering and filtration. Shape of isolines and general image of the NPEMFE field make it possible to highlight anomalies of low values as well as to determine their dimensions. The NPEMFE method is a "quantitative" one; thus, while interpreting the image, fields lie relative to the value – increasing or decreasing in the pulse number within certain period of time.

In 2013, according to the results of field studies, certain sites of filtration and watering were singled out within the western side and within the joint zone of western and southern sides. Total length of the sites is 46 m. According to the VES data, ground water level (GWL) right under the sides was at the depth of 7.5 m; at the distance of 20 m, the depth was 13.0 m (Fig.13). According to the formula by V.V. Vedernikov, filtration losses were 86.02 m^3/day [37].



a *b*

Fig. 12. Schematic maps of the density of pulse flow of magnetic component of the NPEMFE within the retention basin of Kalynivska irrigation system during different years of observation: a – 2013; b – 2017; 1, 2, 3 – filtration sites; НПС – boosting pump station. Crosshatching – zones of pulse absorption and their numbers. Stars – VES points. Coloured scale characterizes density of the magnetic component flow, in pulse/sec. Basin is filled. Coordinate system is conditional, metric

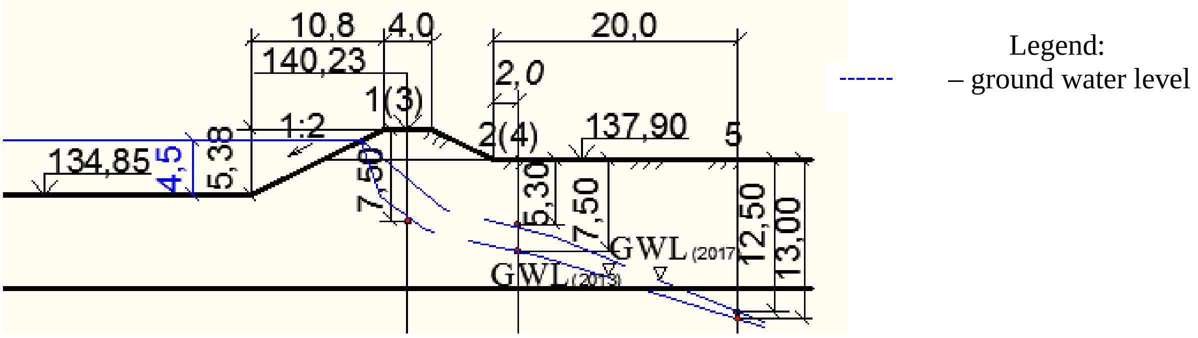


Fig. 13. Comparison of the ground water level according to the surveying data in 2013 and 2017

In autumn 2017, technical state of RB of Kalynivska irrigation system was monitored involving the same complex of geophysical diagnostic methods – NPEMFE and VES. The same zones of filtration and watering were singled out on the maps of the density of the NPEMFE magnetic component flow. However, according to the results of field surveying in 2017, increase in the length of filtration zones due to improper technical condition of RB western side has been defined. Within the southern side, length of filtration zones has increased by 42 m; value of filtration losses is 161.4 m^3/day or 4842 m^3/month. When five-month irrigation period is completed, financial losses will be UAH 96.84 thous. taking into account average cost of irrigation water being 4 UAH/m^3. Geophysical operations in terms of the retention basin of Kalynivska irrigation system cost UAH 17.0 thous. being by 5.7 times lower comparing to the monetary equivalent of the lost irrigation water.

GWL rise by 0.5 m within the territory neighbouring the basin within the period of 2013-2017 can be explained by the studies carried out during different seasons. Deterioration of RB technical state within the period of 4 years makes it possible to assume that redistribution of filtration water around the basin took place during the irrigation interval in 2013; due to that fact, GWL rose from 13.0 m to 12.5 m at the distance of 20 m from the RB.

Thus, singling out of filtration zones in terms of HES earth dams involving the NPEMFE method is rather expedient both practically and economically, which is proved by the corresponding work order by the Regional Office of Water Resources of Dnipropetrovsk Region.

Conclusions. Results of the laboratory compression and field monitoring studies have proved the possibility of applying geophysical electric surveying method of natural pulse electromagnetic field of Earth (NPEMFE) to localize the water filtration sites and broken state of earth dams of agricultural HESs.

According to the results of compressive studies, it has been demonstrated that the increase in stressed state of sandy loam and argillaceous soils corresponds to gradual rise of electromagnetic radiation amplitude, and its drop is characteristic for soil relaxation after the loading removal. In terms of retention basins, that may be interpreted as the increasing action of loading on the soil, when the basin is water-filled; as for the loading decrease that occurs in terms of basin emptying.

Possibility to detect the zones of EMR absorption using the NPEMFE method along with the VES technique allows both determining filtration zones and ground water levels and evaluating nonproductive water losses from the earth HESs of the irrigation systems. It should be noted that the first method is a “qualitative” one, i.e. it helps localize the sites of broken technical state of the earth HESs, which are not found visually. Efficiency of the use of quick and low-cost NPEMFE method is proved by high frequency of the results of technical state monitoring of the retention basin in 2013 and 2017.

Within more than 10 years of observations of technical state of the earth HTSs of CC1 structure category, the authors have emphasized following regularity [3-6]: almost all the retention basins are characterized by sufficient state of the bottom; zones of excessive moistening and filtration within the bottom areas of the basins have not been recorded, which is possible to be explained by colmation of fissures with sludge deposits.

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EXPERIMENTAL SUBSTANTIATION OF THE NPEMFE GEOPHYSICAL METHOD TO SOLVE ENGINEERING AND GEOLOGICAL PROBLEMS

Topicality. Preservation and increasing of soil fertility is the essential problem for the agricultural melioration. It was solved in the most intensive way during the period of 1960s-1980s within the framework of "Large-scale program of the melioration development". Poor technical condition of the internal economic network of Dnipropetrovsk Region is peculiar for more than 136 thous. ha being 68.6 % of the irrigation land area. That results in considerable filtration losses, which stipulates both increased prime cost of the irrigation water and deterioration of environmental and melioration conditions of the neighbouring territories. For a long time, reconstruction of the irrigation system has not been financed properly. Implementation of the measures aimed at restoration and development of irrigation is one of the priorities of the Agreement on the Association between Ukraine and the European Union.

Nowadays, much attention is paid to diagnostics of technical state of hydroengineering structures (HES) in melioration systems of CC1 structure category (especially, to the retention basins of irrigation systems) involving non-destructive instrumental methods.

According to the recommendations of normative documents, it is proposed to determine the zones of increased filtration within the earth dam body, protective dams, and reservoir beds using a system of geophysical methods including the following ones: vertical electric sounding (VES), microelectric sounding (MES), electric profiling (EP), and method of natural electric fields (NEF).

Unfortunately, the mentioned methods are often rather cost- and labour-consuming ones. That emphasizes the topicality of developing and implementing the innovative methods for complex evaluation of technical condition and detection of hidden filtration zones within the bodies of earth HESs. That will help localize and maintain timely the identified site making it possible to prolong operation period of the object and prevent rise of ground water level within the neighbouring territories.

Objective of the paper is experimental substantiation of the efficiency of using labour- and time-saving geophysical NPEMFE method to detect filtration and watering zones, being undetected visually, within the hydroengineering structures of melioration systems to improve their operational qualities, reduce their maintenance cost, and prevent deterioration of environmental and melioration conditions of the neighbouring territories.

Research methodology. The following conventional methods were applied during the scientific and engineering survey activities: field – geophysical research methods NPEMFE and VES to determine filtration zones, which were not detected visually; experimental – involving odometer of standard modification to detect electromagnetic radiation during the loading of loose argillaceous soil samples; laboratory - standard techniques to specify physical and mechanical properties of soils before and after their compressive studies; computational-analytic – to determine dimensions of filtration water losses from the basin. Golden Software Surfer 8 and AutoCad 10 programme complexes were applied to process the obtained results.

Scientific novelty of the research results. For the first time, it has been proved experimentally that electromagnetic radiation increases when loaded with loose argillaceous samples and decreases when the samples are moist. That makes it possible to apply the NPEMFE method to identify visually non-detected filtration zones within the body of hydroengineering structures of melioration systems.

Practical value of the research: possibility to use time- and labour-saving NPEMFE method to identify visually non-detected zones of filtration and watering within the body of hydroengineering structures in melioration systems of CC1 structure category has been substantiated experimentally.

Keywords: method of natural pulse electromagnetic field of Earth, method of vertical electric sounding, odometer, loose rocks, electromagnetic pulses, earth hydroengineering structures, diagnostics of technical condition.

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