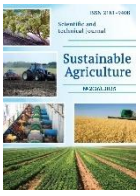
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The Role of the Composition and Thickness of a Gravel-Sand Mixture in the Formation of a Stable Filter of Vertical Wells of Vertical Drainage

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a r t i c l e i n f o

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vertical drainage, gravel-sand mixture (packing), inlet flow rates, aquifer, high-rate wells, rate stability, rotary drilling rigs.

a b s t r a c t

SANIIRI Drainage Laboratory (NIIIVP) carried out a set of laboratory and production studies to clarify the composition of the backfilling of vertical drainage wells, which were included in the "Instruction for the design of irrigation systems" (Part VIII. Drainage on irrigated lands , VSN-II-8-74). Studies on sector flumes found that in order to reduce the input velocities to the filters, it is necessary to increase the diameter of the well (packing thickness), at which the inflow to it will occur in a laminar mode with an increase in water- holding capacity and well flow rate. The author clarified the formulas of SK Abramov and IF Volodko for determining the allowable input velocities in the filters of vertical drainage wells and gave recommendations for the construction of vertical drainage wells of large diameter (1500-2000 mm and more), which will halve the content of fractions with a diameter 1-5 mm, ie reduce the requirements for gravel-sand filling.

1. INTRODUCTION

Vertical drainage is widely used in the Republics of Central Asia, including the Republic of Uzbekistan, as the most effective means of regulating the water-salt balance of irrigated lands [1,2]. Currently, there are more than 4124 vertical drainage wells in Uzbekistan, built in various hydrogeological and reclamation conditions, and 3451 water wells for use for domestic drinking purposes and irrigation. The scientific basis for calculating vertical drainage wells, technologies for their construction and methods for selecting the composition of gravel-sand fills were developed at SANIIRI (NIIIIVP) and published in a monograph, and subsequently the construction of vertical drainage wells is intensively carried out in Uzbekistan in accordance with Presidential Decrees dated 04/19/2013 and 02/07/2013 .2017 and others [3.4.5].

In SANIIRI drainage laboratory (NIIIIVP), we carried out additional research on the selection of the composition of the fills both in field and in laboratory conditions, clarified some parameters for calculating the inlet velocities into the filters, for the first time, we made calculations of the composition of gravel fills for suffosion and non-suffosion aquifers of the Hungry Steppe, Bukhara region, some research results on increasing the diameter of drilling high-yield vertical drainage wells are recommended for implementation [6,7]. The results of these studies formed the basis for the calculation of vertical drainage wells with optimal parameters.

The practice of operating vertical drainage wells, confirmed by theoretical calculations, has shown that the best material for forming a stable well filter is mixed-grained rounded gravel from natural quarries with fractions of 1-10 mm for fine-grained ones; 1-20 mm for fine-grained and medium-grained and 1-30 mm for coarse-grained and gravelly aquifer soils. Moreover, the composition of the sprinkles contains fractions of 1-5 mm for fine-grained and 1-10 mm for fine-grained and medium-grained sands should be at least 50-60%. SANIIRI recommendations for selecting the composition of gravel fills depending on the particle size of aquifer soil are still used by design organizations in the countries of the Central Asian region (Uzbekistan, Kazakhstan, Kyrgyzstan, Turkmenistan, Tajikistan), since they were included in the regulatory documents, they also set out the SANIIRI methodology on the calculation of structural elements of the water intake part of vertical drainage wells, compiled with the participation of the author.

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The practice of constructing high-yield vertical drainage wells in Uzbekistan and Turkmenistan has shown that creating an artificial filter around a perforated frame in accordance with the fractional composition of the aquifer is only the first stage in the formation of a stable filter. The formation of a stable filter occurs during the process of construction pumping due to the removal of small particles and the deposition of larger particles of the aquifer on the outer surface of the filter, as well as due to the reformation of the gravel packing itself. Therefore, when constructing wells, great attention must be paid to the mode of construction and operational pumping.

In those wells where the fractional composition of the filling is selected in accordance with the granulometric composition of the aquifer, i.e. interlayer coefficient is within $\frac{D_{50}}{d_{50}} \leq 35$, the duration of pumping is 5-10 days, during the formation of the filter there is no subsidence of wellheads and there is no need for additional backfilling of a mixture of gravel and sand into the bottom hole.

2. MATERIALS AND METHODS

To ensure laminar flow in the near-filter zone, it is necessary to build vertical drainage wells of large diameter (1500÷2000 mm or more), with a filter frame diameter of 326÷426 mm, the thickness of the gravel-sand filling will be 700÷900 mm. This will reduce the input speeds and sanding of wells, increase well flow rates and halve the content of particles with a diameter of 1-5 mm, i.e. reduce the requirements for gravel filling.

The research used a methodology for selecting the composition and thickness of the coatings, developed at SANIIRI with the participation of the design institutes "Uzgiprovodkhoz" ("Uzdavsuvloyiha"), Sredazgiprovodkhlopok (LLC UzGIP), the author tested the possibility of using the methods of the institutes VNIIG named after B.E. Vedeneev, Bel NIIM and VKh , VNIIG and M, MGMI, Central Research Institute of Municipal Drying, etc. when calculating the design parameters of vertical drainage wells.

3. ANALYSIS OF THE CURRENT STATE OF THE PROBLEM. THE INFLUENCE OF THE THICKNESS OF GRAVEL ON THE FLOW REGIME IN THE NEAR-FILTER ZONE.

Analysis of research materials (Russia, Germany, USA, etc.) showed that in order to reduce pressure losses and flow velocity and increase the service life of wells, the water capture capacity of the filter frame must be calculated from the condition of maintaining the linear filtration law in the near-filter zone. Research by F.F. Engel (Germany) has established that in order to comply with the conditions of laminar flow when approaching wells, a sharp increase in the diameter of the well and the thickness of the gravel packing is necessary. In German wells, two or three layers of filling are used, with a thickness of each layer of at least 80 mm. The smallest final diameter of the wells in Germany was 610 mm, reaching 1600 mm with three-layer filling. F.F. Engel established that salt overgrowing and siltation occurs not only on the entire surface of the well frame, but also on gravel and aquifer soil at a distance of 0.5-1.0 m from the perimeter of the frame. H. Truelsen (Germany) noted that despite the high mineralization of groundwater, some wells are not subject to siltation and overgrowing with salts, since the influx to them occurs during laminar movement, while the oxygen in the air and that located in the pores do not affect the mineralization of the incoming water . By increasing the diameter of wells in Germany, the receiving surfaces of wells increase by 3-4 times, the input speeds, which ensure laminar movement, are reduced, and the water-capacity and flow rates of wells naturally increase.

The water-capacity of wells is also related to the porosity and diameter of the filter frame. According to S.K. Abramov and S.V. Komissarov (VNII VODGEO), normal operation of wells can be ensured by a filter frame duty cycle of 15-20%. SANIIRI research has established that the porosity of the filter frame should match or be slightly greater than the porosity of the contacting layer (in this case, a sand-gravel filter) and is recommended to be at least 25-30%. For wells laid in the Golodnaya Steppe, the duty cycle of pipes with round perforations was 16.9-21%, with slotted ones - 14-25%; the duty cycle of pipes with round and slotted perforations in wells laid in Turkmenistan ranged from 12.5 to 15%, which is clearly insufficient for high-yield wells. The recommendations of foreign researchers (USA) on the choice of duty cycle and perforation of the filter frame coincide with domestic experience, while the thickness of the gravel layer was 150-200 mm [8, 9,].

An analysis of the reporting materials showed that the diameter of wells drilled in the Central Asian republics ranged from 500, 1000 and 1270 mm (6 wells in the Kopetdag Plain were drilled with a diameter of 1200 mm); the diameter of the filter frame varied from 219 to 426 mm. At the same time, the thickness of the gravel filling of the wells laid in the Hungry Steppe was 250-300 mm, in the Kopetdag Plain - 200-400 mm, in the Chardzhou oasis - 355 mm. Most researchers involved in the selection of the composition of the filling and its rational thickness believe that for gravel filters created by backfilling into the face, the minimum thickness of the filling should be in the range of 150-400 mm or more.

A theoretical solution to the issue of the influence of the thickness of the gravel filter on the filtration flow regime in the bottomhole region and an explanation of its physical meaning was given by V.M. Gavrilko and N.D. Bessonov (VNII VODGEO), they believe that when pumping water from a well, a violation of the linear filtration law occurs in the immediate vicinity of the well (in the filter zone); under certain conditions, the area of laminar filtration crisis may expand. Studying the general law of filtration (Proni), V.M. Gavrilko and N.D. Bessonov came to the conclusion that at a constant value of the turbulence index and the inlet filtration rate, as the thickness of the gravel filter increases, the degree of deviation of the fluid movement regime in the near-filter zone from linear filtration law. Thus, the stability of laminar filtration in the bottomhole region of wells is ensured by increasing the diameter of this zone (the thickness of the gravel packing), which is advisable not only from the point of view of increasing the well production rate, but also from the point of view of the stability of well operation, the stability of its production rate over time [10, eleven].

The permissible input speed should be taken according to the modified formula S.K. Abramov (KirGNIIVH, M.A. Sabitov and SANIIRI, S.S. Khodzhaev), which were obtained as a result of laboratory and experimental studies:

Vg = 90-120; (1)$\sqrt[3]{К_ф}$

Based on the experience of operating wells with gravel filters in the Golodnaya Steppe SANIIRI, the following dependencies are recommended for determining the size of the filter frame opening:

for round perforation Dot = 1.2÷1.5 D_{50};

for slot perforation vsh = 0.75÷1.0 D_{50};

lsh = 25÷35 D_{50};

where: Dhole – hole diameter, mm;

Kf – filtration coefficient of aquifer, m/day;

V_{sch}, lш – width and length of the slots, respectively, mm;

D_{50} – average diameter of gravel particles, mm;

4. RESEARCH RESULTS.

Operational practice has shown that wells equipped with thick gravel filters, compared to other filter designs, not only have high flow rates, but are also more stable and longer-lasting over time. At the same time, a thick layer of coating also increases the suffusion resistance of rocks in the filter zone (especially under variable operating conditions), ensuring minimal pressure losses. The above shows that the construction of high-yield wells is associated with the creation of a thick layer of gravel in the filter zone and, naturally, with large drilling diameters. Drilling of such wells in Uzbekistan, Turkmenistan, Tajikistan, Kyrgyzstan and Kazakhstan using rotary drilling rigs with direct circulation, and subsequently rotary drilling rigs with “reverse circulation” made it possible to drill wells with a diameter of up to 1270 mm in loose rocks at high speed [12, 13].

In connection with the drilling of such wells, the question arose to what extent it was possible to increase the thickness of the gravel packing and the diameter of drilling vertical drainage wells. Research by V.N. Shchelkachev showed that the greatest influence on the production of wells is exerted by the construction of a zone with altered permeability (gravel packing) in the immediate vicinity of them. Thus, an increase in permeability by 10 times (K0 = 10 K) in the zone r0 = 0.5 m (from the axis of the wells) leads to an increase in flow rate by 22%, in the zone r0 = 1 m - by 40% (at r = 10 cm and influence radius R=200 m). Obviously, the intensity of flow rate increment for filters with h = 21.3 cm in the zone r0 ≥ 1 m will be more significant than for r = 10 cm. In general, with an increase in the radius of the zone with changed permeability, the intensity of flow rate increment should fade. This was confirmed by laboratory studies conducted by the author at SANIIRI on sector trays, where fine-grained sand with an average diameter of 0.23 mm and a heterogeneity coefficient of 2.5 was used as aquifer. Specially selected gravel-sand mixtures of fractions with a diameter of 1-20 mm, with a layer thickness of 85, 135 and 230 mm, were used as filling in the trays.

Research has concluded that the sufficient thickness of the bedding for these soils from the point of view of ensuring water-capacity is 230÷250 mm, but from the point of view of the stability of well operation and stability of flow rate over time, these thicknesses are insufficient. N.D. Bessonov, having considered the equation of water movement when deviating from Darcy's linear law, came to the conclusion that a thick layer of gravel packing provides a calmer (close to laminar) mode of movement in the filter zone and, thereby, contributes to longer operation of wells and stability of their flow rate. In drilling practice, when calculating the inlet filtration rate, which ensures laminar flow, the empirical dependencies of Gross, V. Zichardt, S.K. Abramov, I.F. Volodko, S.V. Izbash, L.I. Kozlova and others are used.

The author made calculations of the inlet velocities into the filters of typical vertical drainage wells built in the Golodnaya Steppe, as well as the diameter of the wells and the thickness of the fillings. The actual filtration rate was determined by the formula:

$$v_d = \frac{Q}{\omega \cdot m}; \quad (2)$$

where: Q – actual well production;

ω– filter surface area;ω

m – porosity of gravel packing, m=0.30.

Allowable filtration rates were determined using the formulas of S.K. Abramov and I.F. Volodko:

$$(3) v_A = 65 \sqrt[3]{\kappa_f}$$

$$(4) v_B = 36 \sqrt{\kappa_f}$$

Calculations have established that the values of permissible filtration rates according to both formulas are close to each other; actual filtration rates were 1.1÷1.35 times higher than permissible. This is considered quite acceptable, because a slight turbulization of the flow during construction pumping is useful both for the formation of the filter itself and for the removal of sludge that has passed into the bedding and into the aquifer.

The diameter of the filter frame was calculated based on actual filtration rates according to the following relationship:

$$(5) D_{ф.к.} = \frac{Q \cdot m}{П \cdot l_ф \cdot \eta \cdot v_д}$$

where: η=0.25 – duty cycle of the filter frame.

As a result of comparing the actual and calculated diameter of the filter frame, it was found that the actual diameter of the filter frame in almost all wellsGolodnaya steppe was 1.05-1.3 times higher than calculated. In other words, in the well design, the diameter of the filter frame was obviously slightly increased, which, in addition to providing the necessary water-capacity, also contributed to a decrease in the inlet filtration rates.

N.D. Bessonov recommends the following dependencies for determining the drilling diameter and thickness of the filling of long-term wells:

D=(4÷5) Df.k.; tf = (1.5÷2) Df.c.;

where: D – drilling diameter, mm;

Df.k. - diameter of the filter frame, mm;

tf – coating thickness, mm.

In the wells built in the Golodnaya Steppe on the V.I. Lenin collective farm, the Dzhetysaysky state farm, on the Sardobinsky and Shuruzyaksky massifs, the ratio of drilling diameters and filter frame was 2.4-3, and the thickness of the filling was (0.7- 1.0) Df.c.

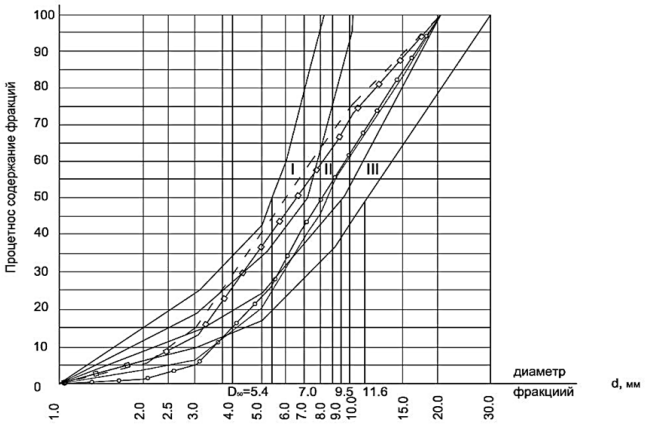
The analysis showed that in order to create reliable high-yield wells it is necessary to install gravel packs of great thickness. If we use the dependences of N.D. Bessonov, then the recommended thicknesses of fillers and drilling diametersI will make up:

tmin = 639 mm and Dmin = 1704 mm; tmax = 852 mm, Dmax = 2130 mm. The construction of large-diameter vertical drainage wells (1.5-2.0 m) is desirable from the point of view of not only operational reliability, but also reducing the requirements for gravel filling.

Laboratory studies and results of production research authorand allowed us to conclude that it is possible to halve the content of fractions with a diameter of 1-5 mm. Figure 1 shows the integral curves of gravel packings used in the most typical high-yield vertical drainage wells of the Dzhetysaisky state farm, which are plotted on the recommended graphs for selecting the composition of packings for fine-grained, medium-grained, coarse-grained and gravelly sands when drilling large-diameter wells.

Reducing the requirements for gravel filling will make it possible to establish their industrial production, and the cost of such filling will be lower than the currently used gravel-sand mixtures based on Bekabad gravelme and Jumin sand.

In the period 1970-1990. In the Golodnaya Steppe, rotary drilling rigs with "reverse flushing" of the Romanian type FA-12 were used to drill vertical drainage wells with a diameter of 1270 mm or more. It is shown above that the construction of large-diameter wells (1500-2000 mm) with a powerful gravel packing 700-900 mm thick ensures a calmer (laminar) mode of movement in the near-filter zone, ensures stability of operation and stability of flow rate over time. Based on the above, it is proposed to include in the forecast parameters of reclamation machines and mechanisms (Uzmeliomashlizing company) supplied to the Republic under leasing the purchase of rotary drilling machines with "backwashing" of foreign production (Romania, Germany, etc.) for drilling wells with a diameter of 1500-2000 mm and more [14, 15].



Sand zones: I – fine- and fine-grained sands, II – fine- and medium-grained sands, III – medium-coarse-grained and gravelly sands,

Integral curves of the compositions of gravel packs used in typical wells of the Dzhetysaisky state farm: -----"-----"----- well 6; — — — — ; well 7○○○○ well 15;——□——□——well 18.

Figure 1. Determination of nitrate content in leaves using LAQUA (Twin Pocket Meters).

5. CONCLUSION:

Laboratory studies in SANIIRI (NIIIIVP) on sector trays have established that in order to reduce the inlet velocities into the filters, it is necessary to increase the diameter of the well (thickness of the coating), in this case the inflow to it will occur with laminar movement with an increase in the water-capacity and flow rate of the wells. The refined formula of S.K. Abramov and I.F. is given. Volodko to determine permissible input velocities into filters of vertical drainage wells.

- As a result of analyzing the operation of some high-yield wells built in the Golodnaya Steppe, the author recommends constructing wells of large diameter (1500-2000 mm or more), which will halve the content of the fraction with a diameter of 1-5 mm, i.e. reduce the requirements for gravel filling.

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