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Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

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КАЗАХСТАН
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INFLUENCE OF THE HYDROGEOLOGICAL MODE OF OPERATION ON THE CHARACTER OF COLLATING OF THE FILTER AND THE FILTER ZONE OF SEASONAL WELLS

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Abstract. The regularities influence of the hydrogeological mode of operation on the nature of filter colmatation and near-filter zone of wells for watering pastures and of the change in the pressure loss gradient in the thickness of the near-filter zone in time have been studied. It is shown that the decrease in the flow rate of water wells is due to various types of clogging of filters and near-filter zones and depends on the operating mode of the wells. It has been established that the predominant influence on the decrease in the flow rate of water wells for watering pastures is exerted by the processes of mechanical clogging of their filters and near-filter zones, which are the result of suffusion of the water-bearing soil with the blocking of the filter inlets and filling the pores of the gravel bed, which is facilitated by the uneven operation of the wells. The size of the bridging zone does not exceed 100 mm, and silt, clay and sand particles with a particle size of less than 1 mm are bridging. And consequently, the methods of restoring the flow rate

of water wells for watering pastures should be aimed at eliminating the consequences of mechanical colmatation of the water intake part.

Key words: watering pastures, groundwater, water well, filter and near-filter zone of the well, debit reduction, mechanical and chemical clogging, debit recovery

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ГИДРОГЕОЛОГИЯЛЫҚ ЖҰМЫС РЕЖИМІНІҢ СҮЗГІЛЕРДІ ЖӘНЕ МАУСЫМДЫҚ СҮЗГІЛЕРДІҢ СҮЗГІЛІК АЙМАҒЫНДАҒЫ БІТЕЛУ СИПАТЫНА ӘСЕРІ

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Аннотация. Гидрогеологиялыќ жұмыс режимінің сүзгінің бітелу сипатына және жайылымдарды суаруға арналған ұңғымалардың сүзгіге жақын аймағына әсері және уақыт бойынша сүзгіге жақын аймаќтың қалыңдығындағы қысым жоғалту градиентінің өзгеру заңдылықтары зерттелді. Су ұңғымаларының дебитінің төмендеуі сүзгілердің жєне сүзгіге жақын аймақтардың бітелуінің әртүрлі түрлерімен байланысты және ыңғыымалардың жұмыс режиміне байланысты екені көрсетілген. Бітелу аймағының өлшемі 100 мм-ден аспайды, ал лай, саз және ќұм бөлшектері 1 мм-ден аз мөлшердегі бөлшектер бітелуге

алып келеді. Құрылыстың белгілі бір тоқтаулары бар суару пункттеріндегі ыңғымаларды, сондай-ақ суару және тік дренаждық ыңғымаларды пайдаланудың маусымдылығымен сипатталатын Қазақстандағы құрғақ жайылымдарды тарату желісінің бар болуы жағдайында олардың жұмысы әсіресе сүзгі аймағында суару және тік дренаждық ыңғымаларды пайдаланудың маусымдылығымен сипатталады. Сүзгі мен сүзгіге жақын аймақтың бітелу сипатын анықтау үшін суды алудың әртүрлі режимдерінде осы аймақтағы қысым жоғалту градиентінің өзгеру ерекшеліктері зерттелді. Қысым жоғалту градиентінің қарқынды қалпына келуі суды алудың тұрақсыз режимінде жүреді, ал біркелкі режимде өзгеріс сүзгіге жақын аймақтың бүкіл қалыңдығы бойынша тұрақтанады. Суды алудың тұрақсыз режимінде 70 мм қалыңдықтағы қиыршық тас төсенішінде және іргелес аймақта қондырғы 20 күн жұмыс істегеннен кейін топырақтың механикалық құрамы үлкен гетерогенділікке ие. Бұл топырақ бөлшектерінің тығыздалуына, су өткізгіштігінің төмендеуіне әкеледі. Судың бірқалыпты қозғалысы кезінде су қоймасынан ұсақ бөлшектерді шығару процесі айтарлықтай әлсірейді, бұл кері сүзгі заңы бойынша сүзгіге жақын аймақта құм түйіршіктерінің топтастырылуымен байланысты.

Түйін сөздер: гидрогеология, геология, жер асты сулары, сүзгіге жақын аймағы, механикалық және химиялық бітелу, суды алу режимдері, су арынның градиентінің жоғалуы.

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ВЛИЯНИЕ ГИДРОГЕОЛОГИЧЕСКОГО РЕЖИМА ЭКСПЛУАТАЦИИ НА ХАРАКТЕР КОЛЬМАТАЦИИ ФИЛЬТРА И ПРИФИЛЬТРОВОЙ ЗОНЫ СКВАЖИН СЕЗОННОГО ДЕЙСТВИЯ

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Аннотация. Исследованы влияние гидрогеологического режима эксплуатации на характер кольматации фильтра и прифильтровой зоны скважин, обводнения пастбищ и закономерности изменения градиента потери напора в толще прифильтровой зоны во времени. Показано, что уменьшение дебита водозаборных скважин обусловлено различными видами кольматации фильтров и прифильтровых зон и зависит от эксплуатационного режима работы скважин. Размер закольматированной зоны не превышает 100 мм, а кольматирующими являются пылеватые, глинистые и песчаные частицы крупностью менее 1 мм. При сложившейся сети распространения аридных пастбищ Казахстана, отличающейся сезонностью использования скважин на водопойных пунктах с определенными простоями сооружений, как и скважинах орошения и вертикального дренажа, в значительной мере усложняется сохранение устойчивого режима их эксплуатации, особенно прифильтровой зоны. С целью установления характера кольматации фильтра и прифильтровой зоны были исследованы особенности изменения градиента потери напора в указанной зоне при различных режимах водоотбора. Установлено, что интенсивное восстановление градиента потери напора происходит при неустановившемся режиме отбора воды, а при равномерном режиме изменение стабилизируется по всей толще прифильтровой зоны. При неустановившемся режиме отбора воды после 20 суток работы установки в гравийной обсыпке и прилегающей к ней зоне толщиной 70 мм механический состав грунта обладает большой неоднородностью. Это приводит к более плотной укладке частиц грунта, снижению водопроницаемости. При установившемся движении воды процесс выноса мелких частиц из пласта значительно затухает, что связано с группированием зерен песка в прифильтровой зоне по закону обратного фильтра.

Ключевые слова*:* гидрогеология, геология, подземные воды, фильтр и прифильтровая зона скважины, снижение дебита, механическая и химическая кольматация, режимы водоотбора, градиент потери напора

Introduction

The main source of water supply for pasture areas is groundwater, the intake of which is carried out by shaft wells and boreholes (Torehanov, 2005). During operation, as a rule, there is a decrease in their performance. One of the main reasons for the decrease in well flow rate is the clogging (mechanical, chemical, biological) of filters and near-filter zones of the aquifer, which causes an increase in hydraulic resistance and a decrease in water inflow into wells.

The process of colmatation proceeds at various stages of the operation of water

intake structures, in various geochemical and hydro-geological conditions. As a result of the violation of the chemical equilibrium in the reservoir, associated with the action of a hydrodynamic disturbance in it caused by the pumping of groundwater, and its intensity and nature change in time and space (vanBeek et al., 2017).

In some cases, all types of colmatage can occur. Establishing the prevailing influence of one or another type of colmatation allows a more correct and reasonable approach to the choice of a method for restoring well flow rates (Makaruch et al., 2013).

Well clogging in most cases has two natures: chemical - by deposition of iron oxides (HFO) in the filter holes (Howsam et al., 1995); mechanical - at the interface between the aquifer and the gravel bedding of the well filter in the form of an accumulation of formation particles and colloids (Mc Laughlan, 2002).

Both types are easily distinguishable visually when examining a dismantled pump with water-lifting pipes, with chemical clogging they have a red-brown coating, and slimy biomass is present, and with mechanical clogging, the pump and pipes remain clean (Houben et al., 2007).

When operating wells in aquifers with groundwater prone to the release of clogging formations, one should avoid the uneven operation mode, which results in aeration of groundwater, reliably seal the wellhead, exclude the use of airlift water lifts, check the operation of the check valves of submersible pumps, provide for regular regeneration wells based on the forecast of their productivity decrease (Smith et al., 2010).

With the steady movement of water, the process of removal of small particles from the formation quickly decays (vanBeek et al., 2009). This is explained by the grouping of sand grains in the near-filter zone according to the reverse filter law: the pores between large sand grains are overlapped by smaller fractions (Hoon Young Jeong et al., 2018).

Research results

In the conditions of Kazakhstan, with the existing network of watering places dispersed throughout the pastures, on unproductive pastures with a pronounced seasonality of their use in the distant pasture system, the operation of wells for watering is characterized by frequent withdrawal of small volumes of water, alternating with downtime (Klimentov, 1967).

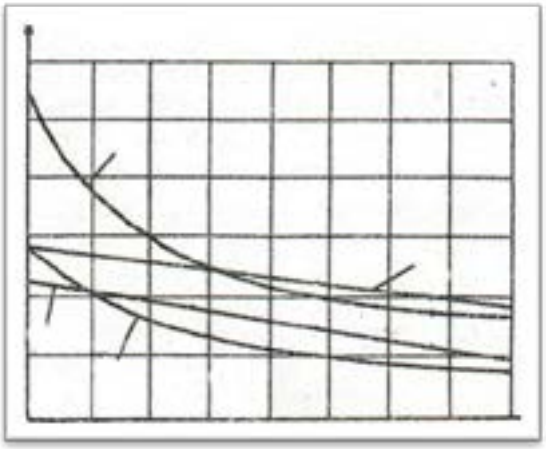
To identify the influence of the well operation mode on the nature of filter and near-filter zone clogging, laboratory studies were carried out. On the filter unit, the water intake part with the near-filter zone of well № 3027/3 was modeled, drilled in the winter pastures of the Uyuk rural district of the Talas district of the Zhambyl region in the sands of Muyun-Kum (Zhaparkulova et al., 2021). The sector filtration tray was loaded with the soil of the aquifer, selected during the drilling of the well (Karmalov et al., 2011).

For 20 days, the filtration plant simulated an uneven water withdrawal regime, typical for wells for pasture watering, and comparison, for 60 days, a uniform (stable) water withdrawal regime. The experimental technique is corresponded to that described (Appelo et al., 2005).

The results of observations of the dynamics of changes in the pressure loss gradient in the soil thickness of the near-filter zone, depending on the location of the considered points from the filter, showed (Figure 1) that an intensive increase in the pressure loss

gradient occurs during an unsteady water withdrawal mode, and in the first 100 mm from the filter (McCarthy et al., 1993).

At the same time, with a stable mode of water withdrawal, the change in the pressure loss gradient occurs evenly throughout the entire thickness of the filter zone, and even after 60 days of operation of the installation, it does not differ much from the corresponding changes that occurred during an unsteady mode of water withdrawal, but after 20 days of operation (Kretzschmar et al., 1999).



1 - with an uneven mode of water withdrawal at the initial moment; 2 - the same, after 20 days; 3 - with a uniform mode of water withdrawal at the initial moment;
4 - the same, after 60 days.

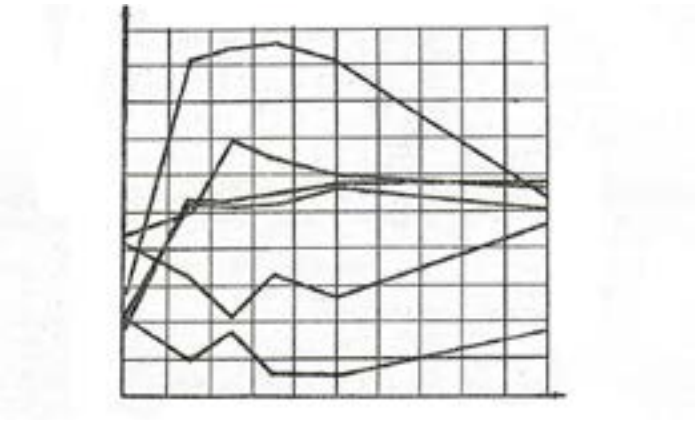
Fig. 1 - Dynamics of change in the pressure loss gradient in the thickness of the soil of the prefilter zone

These changes in the pressure loss gradient are explained by changes, both in quantitative and qualitative terms, in the soils of the near-filter zone, which were the result of the corresponding water withdrawal regimes. This is seen on the graph of the distribution of the mechanical composition of the soil in the thickness of the filter zone (Figure 2). Thus, under a stable water withdrawal mode, the gravel bedding of the filter with a thickness of 30 mm and consisting of gravel particles with a diameter of 5–7 mm received soil fractions of the near-filter zone of different sizes: from 1 % (soil fraction with a particle size of 0.25 mm) to 4 % (soil fraction with a particle size of 0.5–1 mm) (Karmalov et al., 2011). And as can be seen from the graph, this volume of soil was taken out of the adjacent zone with a thickness of 70 mm. In the rest of the filter zone, the distribution of individual soil fractions remains constant (van Beek et al., 2010).

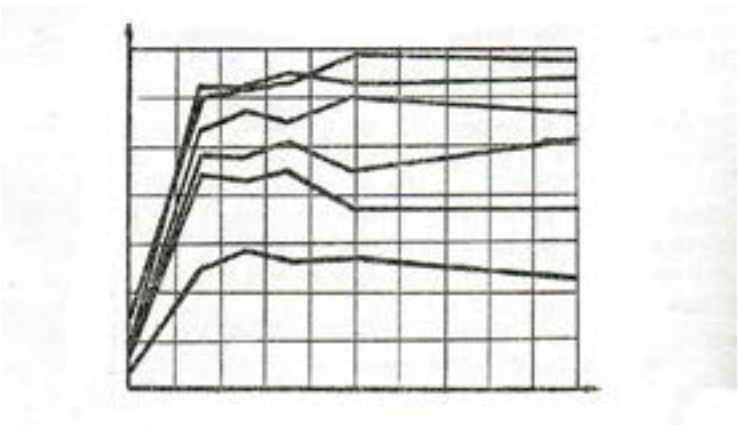
In the unsteady mode of water withdrawal, after 20 days of operation of the installation, the gravel bed received soil fractions of the near-filter zone of different sizes: from 5 % (soil fraction with a particle size of 2–3 mm) to 13 % (soil fraction with a particle size of 0.5–1 mm) (Karmalov et al., 2011). It is difficult to establish the exact boundary of the removal of this soil, since it can be seen from the graph that soil movements

occur throughout the thickness of the filter zone: some fractions are removed, others are introduced. However, the greatest changes in the fractional composition of the soil occur adjacent to the backfill thick zone in the 70 mm (Ustabaev et al., 2022).

Thus, in the unsteady mode of water withdrawal after 20 days of operation of the unit in the gravel pack and the adjacent zone with a thickness of 70 mm, the mechanical composition of the soil has a large heterogeneity, which contributes to a more dense packing of soil particles in this zone, a decrease in its water permeability and, as consequently, an intensive increase in the head loss gradient (Scientific substantiation of the pasture watering system based on GIS technologies for the intensification of distant pastures, 2017).



a) with an uneven water withdrawal mode after 20 days of operation;

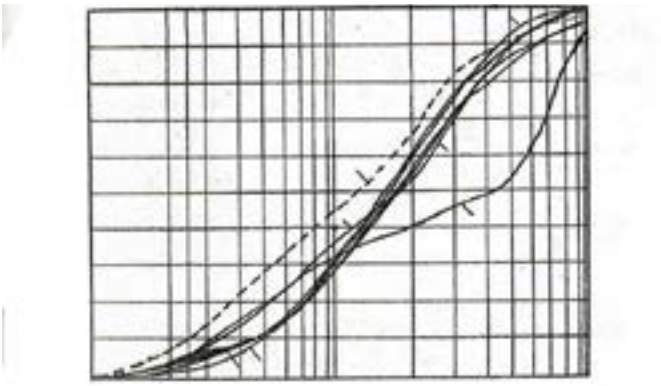


1 - soil fractions with a particle size of 0.25 mm; 2- fractions of soil with a particle size of 0.25-0.5 mm; 3 - soil fractions with a fineness of 0.5-1 mm; 4 - soil fractions with a particle size of 1-2 mm; 5 - soil fractions with a particle size of 2-3 mm; 6 - soil fractions with a particle size of 3-5 mm.

b) with a uniform water withdrawal mode after 60 days of operation

Fig. 2 - Distribution of the mechanical composition of the soil in the thickness of the filter zone

When opening the filtration trays, it was found that with unsteady filtration, over time, the pores of the gravel bed are filled and the inlets of the mesh are blocked by sandy and dusty particles of the water-bearing soil with their gradual compaction and hardening (Makaruch et al., 2013). This is clearly seen from the graph of the mechanical composition of the soils of the near-filter zone in this mode (Figure 3).



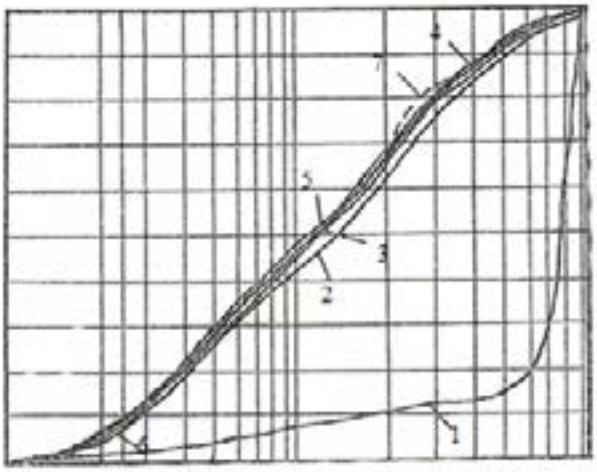
1 - at a distance of 0-30 mm from the filter; 2 - at a distance of 30-50 mm from the filter; 3- at a distance of 50-70 mm from the filter; 4 - at a distance of 70-100 mm from the filter; 5- at a distance of 100-200 mm from the filter; 6 - at a distance of 200-300 mm from the filter; 7 - soil before work

Fig. 3 - Curves of the mechanical composition of soils in the filter zone with an uneven water withdrawal mode after 20 days of operation

The curve of the mechanical composition of the soil of the gravel bed approached the curves of the mechanical composition of the soil of the filter zone. In turn, the last curves have a noticeable separation from each other horizontally (Scientific substantiation of the pasture watering system based on GIS technologies for the intensification of distant pastures, 2017).

With steady filtration after 60 days of operation of the unit, the curve of the mechanical composition of the soil of the gravel pack lies much lower than the curves of the mechanical composition of the soil of the near-filter zone (Figure 4), and the latter curves have slight differences from each other (Mc Carthy et al., 1993). This indicates that the gravel packing is less saturated with fractions of the soil of the filter zone than in the first case, and the soil of the filter zone itself has little qualitative change (Mc Laughlan, 2002).

Confirmation of this conclusion is the comparison of the coefficient of heterogeneity of the gravel pack after the corresponding water withdrawal modes. So after uneven water withdrawal amounted to $k=d_{60}/d_{10}=19$, 58 and after a uniform water intake - only $k=d_{60}/d_{10}=4$, 2 (Ustabaev et al., 2022).



1 - at a distance of 0-30 mm from the filter; 2 - at a distance of 30-50 mm from the filter; 3- at a distance of 50-70 mm from the filter; 4 - at a distance of 70-100 mm from the filter; 5- at a distance of 100-200 mm from the filter; 6 - at a distance of 200-300 mm from the filter; 7- primer before work (Karmalov et al., 2011).

Fig. 4 - Curves of the mechanical composition of soils of the near-filter zone with a uniform mode of water withdrawal after 60 days of operation.

With the steady movement of water, the process of removal of small particles from the formation quickly decays. This is explained by the grouping of sand grains in the near-filter zone according to the reverse filter law: the pores between large sand grains are overlapped by smaller fractions (Kretzschmar et al., 1999).

An analysis of the results of studying the mechanical composition of the soil of the gravel pack and the filter zone, as well as a visual inspection of the state of the gravel pack after opening the filtration trays showed that during unsteady filtration, the formation of stable arches does not occur, but the mechanical movement of soil particles of the filter zone is observed and they fill the pores of the gravel pack. At the same time, with stable water withdrawal, stable summaries are formed for a long time, and gravel packing accumulates particles of water-bearing soil slowly (Ustabaev et al., 2022).

However, in this mode of filtration, sediment has accumulated on the frame and in the space between the frame and the filter shell made of galloon mesh, covering part of the filter surface. On drying, the precipitate crumbled into brown dust (Mc Laughlan R., 2002). With transient filtration, no such phenomena were observed, that is, it can be assumed that self-cleaning occurred, which was facilitated by the filtration mode (Klimentov, 1967). In the first case, the adhesion force of the sediment to the framework elements is many times greater than the force of the filtration flow, and self-purification practically does not occur.

Conclusions

Frequent changes in the mode of water withdrawal from wells under typical conditions of watering pastures and irrigated lands intensify the processes of mechanical

colmatation, which are the result of suffusion of the water-bearing soil with the blocking of the filter inlets and filling the pores of the gravel backfill. The size of the bridging zone does not exceed 100 mm, and silt, clay, and sandy particles less than 1 mm in size are bridging. With unsteady filtration, the formation of stable arches does not occur, but the mechanical movement of soil particles of the near-filter zone is observed and the pores of the gravel filling are filled with them. Stabilization of water intake for a long time forms stable vaults, and due to this, gravel packing accumulates particles of water-bearing soil slowly.It has been established that the predominant influence on the decrease in the flow rate of water wells for watering pastures is exerted by the processes of mechanical clogging of their filters and near-filter zones, which are the result of suffusion of the water-bearing soil with the blocking of the inlet openings of the filter and filling the pores of the gravel bed, which is facilitated by the uneven mode of water withdrawal;

It has been established that the predominant influence on the decrease in the flow rate of water wells for watering pastures is exerted by the processes of mechanical clogging of their filters and near-filter zones, which are the result of suffusion of the water-bearing soil with the blocking of the inlet openings of the filter and filling the pores of the gravel bed, which is facilitated by the uneven mode of water withdrawal;

The size of the bridging zone does not exceed 100 mm, and silt, clay, and sandy particles with a particle size of less than 1 mm are bridging;

Methods for restoring the flow rate of water wells for watering pastures should be aimed at eliminating the consequences of mechanical clogging of the filter and the near-filter zone of the well;

With a uniform water withdrawal regime for a long time, the decrease in the water permeability of the filter and the near-filter zone is carried out mainly due to the manifestation of chemical colmatation processes (Ustabaev et al., 2022);

When operating wells in aquifers with groundwater prone to the release of clogging formations, one should avoid the uneven operation mode, which results in aeration of groundwater, reliably seal the wellheads, exclude the use of airlift water lifts, check the operation of check valves of submersible pumps, provide regular regeneration of wells based on a forecast of a decrease in their productivity.

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