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IMPROVING TECHNOLOGY TO INCREASE THE CAPACITY OF GROUNDWATER INTAKE FACILITIES

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Abstract. The productivity of groundwater intake facilities depends on aquifer properties, well condition, and operating regime. A comparative review of scientific literature supports an approach that combines hydraulic diagnostics, rehabilitation tailored to the clogging mechanism, and repeat testing. Field photographs of hydrodynamic cleaning are used to examine the delivery of pressurized water into the well, deployment of the cleaning device, and removal of released material. The analysis shows that performance assessment should consider stable discharge, acceptable drawdown, water quality, and specific energy consumption together.

Keywords. groundwater, water intake facility, well discharge, clogging, hydrodynamic cleaning, well rehabilitation, nozzle, specific capacity

Аннотация. Производительность водозаборных сооружений из подземных источников зависит от свойств водоносного горизонта, технического состояния скважины и режима эксплуатации. На основе сравнительного анализа научной литературы обоснован подход, объединяющий гидравлическую диагностику, восстановление скважин с учётом механизма кольматации и повторные испытания. На примере фотографий гидродинамической очистки рассмотрены подача воды под давлением в скважину, размещение устройства для очистки и удаление отделившегося материала. Показано, что при оценке эффективности необходимо совместно учитывать стабильный дебит, допустимое понижение уровня воды, качество воды и удельное энергопотребление.

Ключевые слова. подземные воды, водозаборное сооружение, дебит скважины, кольматация, гидродинамическая очистка, восстановление скважины, насадка, удельный дебит

Introduction

Here, the capacity of a groundwater intake facility is defined as the stable volume of water abstracted per unit time. During well operation, increasing hydraulic resistance in screen openings, the gravel pack, and the aquifer surrounding the screen requires greater drawdown to maintain the same discharge. Mineral deposits, microbial growth, and the accumulation of fine particles are major contributors to this process [1, 2, 5]. Consequently, the available discharge may decrease and the energy required to lift the water may increase.

Studies addressing conditions in Uzbekistan discuss combining chelating agents selected for the chemical and mineralogical composition of clogging deposits with hydrodynamic treatment to restore well discharge [3, 4]. Linking this approach to initial well diagnostics and subsequent operational monitoring provides a basis for improving the technology used in groundwater intake facilities.

Research objective and method

The objective is to identify ways to increase the stable productivity of groundwater intake facilities while accounting for well head losses and clogging mechanisms. The method is a comparative review of scientific studies on pumping tests, well rehabilitation, and operation. The

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field trials of hydrodynamic cleaning reported by Omelyanyuk and coauthors, together with the photographs in their Figure 14, were examined to explain the treatment process [6].

Hydraulic diagnostics and assessment criteria

Before selecting a treatment, well discharge, static and pumping water levels, pump performance, and the physical and chemical properties of the water are determined. A step-drawdown test measures discharge and drawdown together. Their relationship can be expressed using the following quadratic approximation [1]:

$$s = BQ + CQ^2 \quad (1)$$

where s is drawdown, m; Q is pumping discharge, m^3/s; and B and C are empirical coefficients representing linear and quadratic head losses, respectively. With these units, B has units of s/m^2 and C has units of s^2/m^5. Houben and Kenrick show that B includes linear losses in the zone surrounding the screen and in the gravel pack, as well as aquifer losses. The coefficient C cannot be equated solely with losses through screen openings [1]. These parameters therefore cannot independently and unambiguously identify the location of clogging.

Rehabilitation performance can also be assessed using specific capacity, defined as the ratio of discharge to drawdown:

$$q_s = \frac{Q}{s} \quad (2)$$

Here, q_s is specific capacity, with units of m^2/s. Comparisons should use the same test duration, comparable discharge rates, and hydrogeological conditions that are as similar as practicable. Assessing water levels, specific capacity, and energy consumption together helps distinguish aquifer changes from the hydraulic resistance associated with well condition [1, 2]. The applicability of the simplified model must be checked separately for unconfined or fractured aquifers.

Rehabilitation tailored to the clogging mechanism

For chemical rehabilitation, the reagent should be compatible with the composition of the clogging deposits and the screen material. Gadayev and coauthors examine the combined use of OEDF and NTF chelating agents and hydrodynamic treatment [3, 4]. These studies emphasize reagent penetration into densely clogged zones and the removal of loosened or dissolved material from the well. Rehabilitation should therefore include reagent delivery, provision of the required treatment action, and removal of treatment products.

The mechanical treatment method is selected according to well construction and condition. Kahuda and coauthors emphasize the need to remove particles released during ultrasonic treatment using a pump or airlift; otherwise, these particles may cause renewed clogging [2]. Hydrodynamic cleaning likewise requires both loosening of clogging deposits and removal of the treatment products [6]. Rehabilitation performance thus depends on the coordinated operation of the treatment device and the process used to remove released material.

The operating regime after rehabilitation also depends on the clogging mechanism. Van Beek examines reducing frequent pump starts and stops where chemical screen clogging results from the mixing of iron-bearing and oxygenated water. For mechanical clogging caused by particle accumulation at the interface between the gravel pack and the aquifer, intermittent pumping with adequate resting periods is considered [5]. Intermittent pumping is therefore not a universal solution for all wells. Pumping and resting durations should be selected using local observations.

Hydrodynamic rehabilitation process and its analysis

Figure 1 shows practical elements of the hydrodynamic well rehabilitation process used by Omelyanyuk and coauthors [6]. It presents a mobile cleaning unit, a treatment mixture being pumped out of the well, and a nozzle holder connected to a high-pressure hose.

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(a) (b) (c)

Figure 1. Practical well rehabilitation operations: a — mobile cleaning unit; b — mixture pumped out of the well during cleaning; c — nozzle holder connected to a high-pressure hose for deployment in the well. Source: Omelyanyuk et al. [6], Figure 14.

Figure 1a shows the mobile cleaning unit mounted on a vehicle. The source describes supplying pressurized water to the well through a flexible high-pressure hose [6]. The nozzle holder in Figure 1c is part of the device lowered into the well to deliver water jets to the treatment zone. Figure 1b shows the mixture discharged during cleaning; the authors used plastic pipes to remove treatment products. These photographs illustrate related functions: delivering hydrodynamic action to the clogged zone and removing released material from the well. The final effectiveness of rehabilitation is assessed through a repeat pumping test [1, 2].

The authors tested cavitation and conical hydrodynamic nozzles in four wells in Krasnodar Krai. They reported discharge increases of 34–121% relative to the rates before cleaning [6]. For example, discharge increased from 50 to 67 m^3/h in well 14 and from 2.4 to 5.3 m^3/h in well 1. These figures are results from the field trials reported in the source. They cannot be treated as a standard expected increase for another well; performance depends on the clogging mechanism, well condition, and aquifer properties.

Improving technology to increase intake capacity

The analysis of the photographs and literature indicates that rehabilitation should be linked to initial hydraulic diagnostics, selection of a suitable treatment method, removal of released material, and a repeat pumping test [1, 2, 3, 4, 6]. The equipment in Figure 1 illustrates the treatment and material-removal components of this approach. After treatment, the assessment should establish whether the same discharge can be obtained with less drawdown, or a higher discharge with the same acceptable drawdown. Water quality and electricity consumption per cubic metre of water are also measured.

In a well field, the discharge of each well is calculated together with pump characteristics and head losses in the collector pipes. Veremenyuk and coauthors apply hydraulic calculations based on discharge and hydraulic-head balances for different combinations of operating wells [8]. On this basis, pump and pipe operating conditions should be recalculated when rehabilitated wells are reconnected to the system.

Where structural modification is necessary, horizontal or radial collector wells are assessed as alternatives. Houben and coauthors describe their potential to provide higher discharge with less drawdown in thin aquifers. However, the benefits of increasing lateral length and number are limited by friction and interference [7]. An increase in well productivity does not imply an increase in aquifer reserves. Long-term water-level changes and depletion of streamflow in hydraulically connected rivers must be considered [9].

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Conclusion

Increasing the capacity of groundwater intake facilities requires the combined use of hydraulic diagnostics, rehabilitation tailored to the clogging mechanism, and management of the operating regime. The mobile cleaning unit, nozzle holder, and discharged mixture in Figure 1 illustrate the connection between applying pressurized treatment and removing treatment products [6]. Improvements in the technology are assessed using specific capacity, acceptable drawdown, water quality, and specific energy consumption. Effectiveness in local wells should be verified through repeat field tests and long-term monitoring.

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