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A method of using wastewater run-off from fish farms having no multi-use hydrosystem with water cleaning technologies

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Abstract: For industrial water use planning, water usage and drainage per unit product standards must be established. This would allow for the conservation of fresh water resources without limiting irrigation in the face of the world's ever-increasing drinking water deficit. Because fish farms use a lot of water, businesses that raise fish in artificial ponds usually dig deep wells to get to the valuable subsurface water they need. Because they lack a reusable water system equipped with treatment technologies, they typically discharge water into the environment after a single use, resulting in marshes, soil salinization, or transportation with surface water flow to the brackish water ecosystem. In recent years, the use of groundwater for fishing has spread in Armenia's Ararat plain, one of the country's most important agricultural regions. The Ararat plain has a water shortage for irrigation, which is mostly addressed by increasing water intake volumes from Lake Sean, a critical source of drinking water. In the absence of a multi-use hydrosystem with cleaning technologies, a method of utilizing fish farm wastewater for irrigation purposes is proposed as a water-saving and environmental-protection approach.

Keywords: fish farm, irrigation, deep well, fresh water, and water ecology

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Introduction

According to UN projections, the world's population will reach 8 billion by 2025, representing a 38% increase over the current level. The International Water Management Institute (IWMI, 2000) predicts 40% more food will be needed to feed the world's growing population. The IWMI estimates a 29% increase in irrigated land area and a 17% increase in water intake (Becker et al., 2017).

Fish production is one of the most appealing investment sectors in Armenia. It has shown and continues to show rapid growth and profitability. Currently, the country annually produces over 16,000 tons of commercial fish. In recent years, there has been a sharp increase in the volume of production of particularly high-value fish species – salmon and sturgeon, which account for roughly 70% of commercial fish production. A significant portion of the fish produced is exported. The average annual growth rate of production volume over the last ten years has been 40%. According to those involved in the fish production industry, Armenia's current capacity allows it to produce approximately 300,000 tons of product per year. One of the most important components of the Government of the Republic of Armenia's agenda is the application of the best modern water saving technologies in the field of fish farming. In September 2013, the government issued an order requiring businesses to implement water-saving technologies in fish farming. The implementation of such technologies in a single fish farm will require an investment of up to 0.7-1.5 million dollars, depending on the size of the farm. To promote environmentally friendly technologies and efficient fish farming practices, a pilot fish farming program using semi-closed water cycle technology is expected to be piloted in the Ararat Valley in collaboration with the Food and Agriculture Organization of the United Nations. In recent years, the base rate used to calculate the water usage fee in the Ararat Plain, where most fish farms are concentrated, has increased tenfold. Thus, in order to increase the efficiency of water use, accurate flow measurement and volume control are critical for both government agencies and businesses. However, from a technical standpoint, installing water meters and implementing a control system may necessitate a substantial investment (Pulatov, 2017).

Water use was increased 30-fold when water conservation measures were combined with production intensification for catfish farming in artificial ponds in the north-western part of Mississippi, USA (*Aquaculture Sector Review Armenia*).

Creation of a scientifically based normative base and its application procedure for effective use of water resources and planning of conservation measures is one of the components of water basin management and water pollution prevention. Organizations that farm fish in artificial ponds by drilling deep wells primarily use groundwater, which is released back into the environment after use. As a preventative measure against this virulent phenomenon Prof. Margaryan, one of the work's authors, proposed a technique of measuring the flow in aqueducts with a mixed mode of water flow in fish farms based on measuring the water flow in the aqueduct through a small diameter pipe (bypass line) connected parallel to the aqueduct decision (Tucker, 2017). This hydrometry method is appropriate when the water from the fountains is supplied to the basins via an almost horizontal pipeline.

1. Purpose, tasks, and research methods

The flow of water used in fish farms is measured using the method defined by the RA standard, in which case the connection unit of the water meter is placed on the bended site, resulting in some inaccuracies in the measurement results. The problem in question is: to improve the scheme of the hydrometric unit in order to eliminate the influence of local resistances on the hydraulic parameters.

Another problem is posed: to assess the efficiency of groundwater use for mechanical irrigation by fish farms operating in the Ararat Valley.

2. Results and discussion

In contrast to the RA standard's method of measuring water flow in water pipes with a mixed mode of flow, it is proposed in this paper, a new flow measurement scheme (Fig. 1). When performing hydrometry on the working pipelines of fountain wells, the characteristics of their operation should be considered (Margaryan et al., 2017):

- relatively small pressure at the starting point of the water pipe,
- the presence of a hydraulic mixed mode,
- the danger of temporary stoppage of water supply.

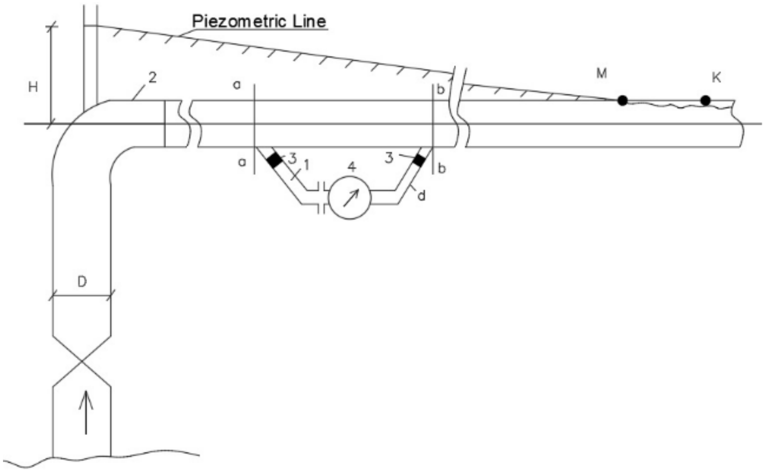

Fig. 1. The schematic diagram of proposed hydrometer unit: 1 – bypass line, 2 – main water pipe, 3 – sealed mounting plug valve, 4 – mechanical water meter, a-a-inlet section, b-b-outlet section, L_1, d, A_1, V_1, q and L_2, D, A_2, V_2, Q are the length of the bypass and main water line *ab* section, diameter, flow section, average velocity and outlets, respectively, H – excess pressure in the initial section of the aqueduct, MK – non-pressure movement section (*own research*)

Pressure movement occurs along some length of the initial part of such a pipeline (up to point M), followed by non-pressure movement. If the water meter is installed directly on the water pipe, the output will be noticeably reduced, which is not permitted. Another feature of the water pipes of such farms is that the supply remains constant throughout the day, and the water temperature is almost constant throughout the year (14°C). Under conditions of a constant output, the meter readings are reliable, i.e., the error is less than in the case of a variable output. The water meter unit consists of a tap of the inlet diameter *d* of the water meter, which is welded horizontally to the pipe stand, and the minimum length of which is $l_1 = 8d$, a water meter of a mechanical *d* diameter, a horizontal outlet nozzle of the same diameter and minimum length, and a pipe of the same diameter connected at an $\alpha = 30°$ angle to the latter, the end of which is welded to the water pipe. A plug valve with a diameter of *d* is installed on the inlet spout 5*d* away from the water meter. The mechanical water meter is flanged to the inlet and outlet taps. The plug valve on the water meter's bypass line is fully open, and the water meter flanges are sealed.

Parallel pipes have equal energy losses, and discharges through them are inversely proportional to 1/2 the power of their hydraulic resistances. Energy losses in the bypass line and the main aqueduct section *ab* are calculated by the following formulae (Margaryan et al., 2017):

$$h_w = \left(\varsigma_1 + \varsigma_2 + \varsigma_3 + \lambda_1 \frac{L_1}{d}\right)\frac{q^2}{2gA_1^2} \tag{1}$$

$$h_w = \left(\varsigma_4 + \lambda_2 \frac{L_2}{D}\right)\frac{Q^2}{2gA_2^2} \tag{2}$$

From the equalization of losses determined by Eqs. (1) and (2) it is obtained:

$$m = \frac{Q}{q} = \frac{A_2}{A_1}\sqrt{\frac{\varsigma_1 + \varsigma_2 + \varsigma_3 + \lambda_1 \frac{L_1}{d}}{\varsigma_4 + \lambda_2 \frac{L_2}{D}}} = \sqrt{\frac{S_1}{S_2}} \tag{3}$$

from Eq. (3) it is followed

$$\frac{\sqrt{\varsigma_1} + \varsigma_2 + \varsigma_3 + \lambda_1 \frac{L_1}{d}}{\sqrt{\varsigma_4 + \lambda_2 \frac{L_2}{D}}} = \frac{V_2}{V_1} > 1 \tag{4}$$

where S1 and S2 are hydraulic resistances of the ab section of the water line and the main water line, respectively, *m* is the ration of the main water line *Q* flow of the ab section and the flow *q* of the bypass line, ς_1, ς_2, ς_3, λ_1 are the resistance coefficients of the bypass line inlet, water meter, local resistance of the angle, ς_4 and λ_2 are the main water line bending and friction resistance coefficients, the magnitude of the *m* coefficient is independent of the pressure *H* of the starting point of the aqueduct and depends only on the hydraulic resistances of the hydrometer unit.

The main aqueduct's flow will be

$$Q_0 = Q + q \tag{5}$$

As far as according to Eq. (3)

$$Q = mq \tag{6}$$

then

$$Q_0 - (m+1)q \tag{7}$$

As a result, in any period T, the volume (flow) of liquid passing through the aqueduct will be

$$Q_0 T = (m+1)qT = m_0 q T;\ (m+1 = m_0) \tag{8}$$

where $W_0 = m_0 w\ (w = qT)$.

The hydrometer node's output ratio is experimentally determined as follows:

a) the sum output Q_0 is measured with an electronic water meter at the pressure point 10D away from the b-b section of the main water pipe hydrometer in the direction of movement,

b) the output passing through the bypass line is determined by a mechanical water meter,

c) the output ratio $m_0 = \frac{Q_0}{q}$ is determined, and the q quantities are taken as the arithmetic mean of several measurements.

A turbine meter can be used as a mechanical water meter. When choosing the diameter of the bypass line and the caliber of the mechanical water meter, it should be assumed that the output confirmed in it exceeds the minimum output of the meter (water meter), so that the reading of the latter is reliable. The diameter of the conventional passage of the meter is equal to the diameter of the bypass line. When $q = (2-3)Q_{\min}$, the calculator's relative error is 0.3%. The diameter of the bypass line and the caliber of the mechanical water meter should be selected in accordance with the diameter of the main water pipe (Margaryan et al., 2017).

Solar power plants can be used for small areas and terrain near plains. The use of such plants is advantageous, particularly in areas where there is no reliable power supply. In the absence of a power supply system, the cost of solar panels per kW of power is currently around 1,400 €.

The use of traditional pumping stations will be effective in the presence of electricity. During the irrigation season, fields at elevations of 40 meters or higher can easily be supplied with discharges of 0.2 m^3/s or greater and distances of 3 km or greater.

Let us evaluate the effectiveness of the proposed project using the example of a medium-sized fish farm in the Ararat valley, where the water output is $Q = 0.2\ m^3/s$, the distance between the fish farm and agricultural land is $L = 4000$ m, and the height is $H_0 = 60$ m. To conduct such outlets, it is advisable to have a velocity of $v = 2$ m/s in the pressure pipeline. Taking into account that output $Q = vA$, where A is the surface of the pipe, we get: $d = \sqrt{(4Q/v\pi)} \sim 0.36$ m. Let us calculate the hydraulic parameters of the pipeline for a $d = 400$ mm pipeline. Because of the pipeline's length, local resistance losses can be ignored. Let us apply it to the calculation of energy losses in metal pipes:

$$h_w = SQ^2 \tag{9}$$

the well-known formula, where $S = 1/K^2$ is the hydraulic resistance of the pipe, and K is the flow rate, the value of which is taken from the relevant tables depending on the diameter of the steel pipe. Because there is no experimental data for determining the flow rate of polyethylene pipes, longitudinal energy losses should be calculated using the Darcy-Weisbach formula, where the value of λ can be taken 0.015, according to Shevelyov's table, the square of the flow rate in our case (steel pipes) when $d = 400$ mm is $K^2 = 4.850$ (m^3/s)^2. Substituting the formula into Eq. (10), we get $h_w = 0.2^2 \cdot 4000/4.850 = 32.9$ m. This is a significant amount of energy lost, and it must be reduced.

If we choose a pipe whose diameter is $d = 450$ mm, then we will have $K^2 = 9.183$ (m^3/s)^2. Substituting the formula into Eq. (10), we get $h_w \sim 17.4$ m. The development pressure of the pump will be $H = H_0 + h_w = 77.4$ m. The useful power will be $N_0 = \rho g Q H = 147$ kVt. The power delivered to the pump shaft will be $N_p = N_0/\eta_p = 147/0.8 \sim 185$ kVt. It is expedient to choose a two-way feed pump. The power of the unit will be $N_a g = N_p/\eta_g = 185/0.96 \sim 193$ kVt. We select the power of the asynchronous motor $N_M = 200$ kVt. Taking the irrigation season as 180 days, let us now determine the amount of pumped water per year $\Sigma W = 15.55\, Q\, 10^6 \sim 3$ mln m^3.

Water intake from Lake Sevan would be reduced by 3 million m^3 per year if the proposed irrigation method were used, and the cost of water supply will be reduced, approximately, twofold. The annual cost of electricity will be: $\Psi = 864{,}000$ kVtour, with a price of around $\Phi \sim 100{,}000$ €. The actual water consumption will be: $\Delta\Phi = \Phi/\Sigma W \sim 0.034$ €/h. To operate this water supply system, regulating basins with a total volume of 20,000 m^3 will need to be built on the highest points of irrigated land, with an annual depreciation cost of around 5,000 €. A steel pipeline with a length of 4 km and a diameter of 450 mm will have an annual amortization cost of around 75,000 €, while polyethylene pipes will have a cost of 30,000 €. The cost of running this water supply system will be around 75,000 € for a pipeline with a length of 4 km and a diameter of 450 mm, and 30,000 € for polyethylene pipes. In other words, the annual cost, including operating expenses, can be estimated at a maximum of 85,000 € per year. As a result, the specific cost of system operation will be $\Delta\Sigma\Phi = \frac{\Sigma\Phi}{\Sigma W} = \frac{185{,}000}{3{,}000{,}000} \sim 0.062$ €. The price of mechanically supplied irrigation water in the Republic of Armenia's considered Sevan-Hrazdanian irrigation system is around 0.1 € (*Resolution N61-A 01.03.2007*). Water intake from Lake Sevan will be reduced by 3 million m^3 per year if the proposed irrigation method is used, and the cost of the water supply will be reduced by approximately twofold.

At the same time, it should be noted that the activities of fish-producing organizations frequently result in the deterioration of the aquatic ecosystem's water quality. The impact of their operations on individual water quality parameters such as clarity, temperature, pH, nitrate, phosphate, salinity, total dissolved solids (TDS), and dissolved oxygen must be assessed (DO). In this regard, it is necessary to investigate the impact of fish farm water on crops.

Conclusions

1. For the flow measurement of the effluents from the fish farms for irrigation purposes, in contrast to the RA standard, it is recommended to place the connection branch at a distance of 50D from the bend site to avoid the effects of local hydraulic losses.
2. In order to prevent the possible deterioration of the water ecosystem, it is suggested to investigate the effect of water taken from fish farms for irrigation on crops.

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