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Rational water consumption under multistage washing

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This report deals with a theoretical approach to the multistage washing system for dispersive materials in soil. At the present time there is growing scientific concern about the multistage washing system which provides important benefits compared to single-stage of the soil washing. Considering the effect of differential intensity of mass-transfer as the specific function of technological parameters on every stage gives some information to get a minimum water consumption.

Key words: *washing, dispersive materials, differential intensity, mass-transfer, rational water consumption.*

1. INTRODUCTION

The multistage washing with differential distribution of water rate on the stages is an efficient system for water-saving. The typical example of this process refers to washing of dispersive materials in soil. The cascade method developed in some works [1-3] utilizes the matter balance and kinetic equations under unequal efficiency and mass-transfer parameters of every stages (Figure 1).

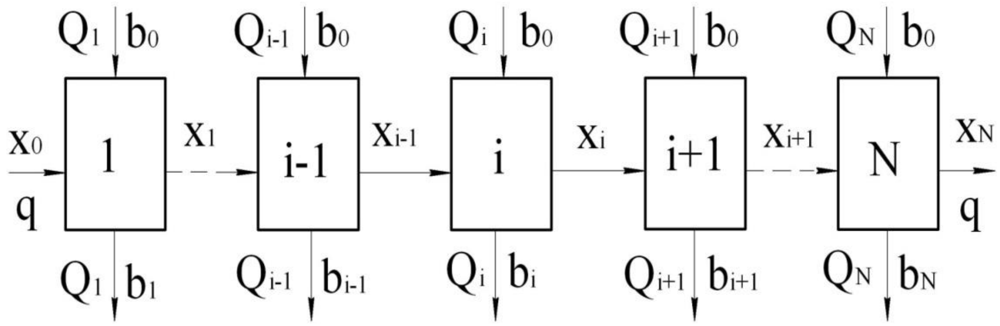

Figure 1. Schema of multistage washing with differential water distribution on stages

2. WASHING WITH DIFFERENTIAL WATER DISTRIBUTION ON STAGES

Assuming that contaminated stagnate zones volume are identical $q_i^{'} \neq idem$ on the every stage but the mass-transfer Fourier numbers are unequal $Fo_i = A_i\tau_i \neq idem$ we can find the optimal water distribution for maximum efficiency [3]. In other words, it is aimed to define the fresh water input for every stage to deliver the minimum relation $\frac{x_N}{x_0} \to \min$ under limited water consumption

$$\overline{Q}_N = \sum_{i=1}^{N} Q_i = const \qquad (1)$$

and efficiency of washing process depends in a complex way on the mass-transfer parameters and water rate factors as follows:

$$E_i = \frac{C_0^{'} - C_i^{'}}{C_0^{'} - C_0} = \frac{1 - \exp[-k_i t_i (1 + Q_i^{-1})]}{1 + Q_i^{-1}}, \qquad (2)$$

where $C_0^{'}$, $C_i^{'}$ – are initial and current average concentration of dispersion material in soil;

C_0 – is the initial average concentration of dispersion material in soil;

k_i – is the volumetric coefficient of the mass-transfer;

t_i – is the time of contact between dispersion material and water;

Q_i – is the ratio of washing water rate q_i to moisture zones rate of dispersion material $q_i^{'}$.

Simplifying for clean water $C_0 << C_i^{'}$ gives efficiency

$$E_i = 1 - \frac{C_i^{'}}{C_{i-1}^{'}}. \qquad (3)$$

After transformation we obtain

$$C_N^{'} = C_0^{'} \prod_{i=1}^{N} (1 - E_i). \qquad (4)$$

Then the multistage washing degree takes the form

$$\overline{C}_N = \frac{C_N^{'}}{C_0^{'}} = \prod_{i=1}^{N} (1 - E_i). \qquad (5)$$

For minimizing the foregoing function the Lagrange system can be utilized

$$\frac{\partial}{\partial Q_i} (\overline{C}_N + \lambda \overline{Q}_N) = 0, \qquad (6)$$

where λ is the Lagrange indefinite multiplier.

This system (6) includes *N*+1 unknowns and may be solved with equation (1). The solution of the explicit system results in the auxiliary function

$$\varphi_i = \frac{\overline{C}_N}{1 - E_i} \frac{\partial E_i}{\partial Q_i} = idem. \qquad (7)$$

Thus, this result points for additive information on the relationship between the technological parameters of the mass-transfer in order to reach more rational clean water use.

3. MULTISTAGE COUNTER CURRENT WASHING SYSTEM

Figure 2 shows some two-stage fragment of the counter current washing. At the present time there is growing scientific concern about the multistage washing system which provides important benefits compared to single-stage of the washing.

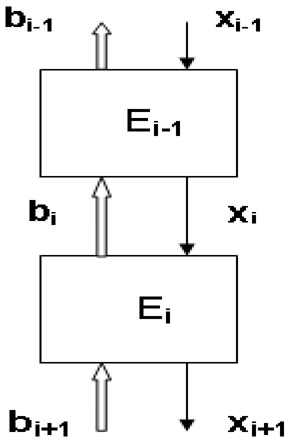

Figure 2. Two-stage fragment of the counter current gravitative washing

In this article our aim is to evaluate chemicals content changes for the last two stages with different efficiency. The equations of the chemical content balance can be written:

$$\begin{cases} F_{i-1} = \dfrac{x_{i-1} - x_i}{x_{i-1}}, \\ x_i = x_{i-1}(1 - F_{i-1}). \end{cases} \tag{8}$$

The chemical content of the pollutant for the next stage results in:

$$x_{i+1} = x_i(1 - F_i). \tag{9}$$

For two stages we have:

$$x_{i+1} = x_{i-1}(1 - F_i)(1 - F_{i-1}). \tag{10}$$

Taking into account eq.(10), target function of washing for two stages will be evaluated as follow:

$$T_i = \frac{x_{i+1}}{x_{i-1}} = (1 - F_i)(1 - F_{i-1}). \tag{11}$$

For example, minimizing this function under $F_i = k_i t_i$ as well as $F_{i-1} = k_{i-1} t_{i-1}$ and conditions $k_i = k_{i-1}$, $t_i + t_{i-1} = const$ can be delivered with $t_i = t_{i-1}$.

As a result of this presentation we can see that any approximation function of efficiency provides minimum relation $\dfrac{x_{i+1}}{x_{i-1}} \to \min$ under $F_{i-1} = F_i = idem.$ So, it is easy to apply such procedure to the following pair of stages and so on.

4. CONCLUSION

Considering the effect of differential intensity of mass-transfer as the specific function of technological parameters on every stage gives some information to get a minimum water consumption. Multistage leaching experience has the evident arguments for the possible usage of limited water rate.

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