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PURIFICATION OF WATER IN NATURAL AND DISTURBED PEATLANDS

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SUMMARY

Mire vegetation and peat deposits provide an important ecosystem service in purifying waste water. The sustainability of vegetation and peat depends on the concentration of dissolved and suspended solids in waste water. This paper presents a model of mire vegetation and peat stability to assess the allowable limit of waste water discharge, at which change in vegetation and peat structure occurs. The surface area of natural mire required for effective water treatment without change in vegetation and peat has been calculated. The cost of water purification function has been calculated by analogy with technical sewage treatment plants. A scheme for waste water treatment for drained peatlands is proposed. The peatland area, peat depth and water treatment time required for purification depend on the waste water volume. The waste water treatment can be performed throughout the year.

KEY WORDS: peatlands, peat, vegetation mires, water purification, service.

INTRODUCTION

Peatlands usage for purification of water with natural and artificial components has a great scientific and practical significance in Russia. Thousands of small towns in the north of European Russia and Western Siberia have no sewage purification systems, so they discharge waste water into the mires without treatment. Mire contamination and restoration observations suggest they have a certain anti-contamination stability potential. The objective of this work is to evaluate parameters of natural and dried mires as systems for water purification without any substantial damage to the mire itself.

MATERIALS AND METHODS

For the economic estimation of the water purification function of peatlands the following admissible water contamination levels above its natural trophic level were chosen (see details in Panov, 2009): a) oligotrophic mire: 10 mg/l and 50 mg/l for its mire vegetation and peat sediments, respectively; b) eutrophic mire: 60 mg/l and 50 mg/l for its mire vegetation and peat sediments, respectively. These values will be accepted as contamination equal to 1. Greater values would mean a critical change in the mire characteristics.

Most contaminants are adsorbed in the layer adjacent to the acrotelm, where the adsorptive properties of the valley peat of low and medium decomposition are comparable to those of the raised bog peats. Their adsorption capacity varies less than 5-7%. Therefore an arbitrary equivalence of the adsorption properties of the valley mire and raised bog has been accepted.

A volume ratio of 1/100 for the mire-purified outflow (U_v, m^3) to the peatland that provides the movement and purification of the wastes (U_t, m^3) is used as a basic parameter of the water-purifying mire (see details in Yampolsky *et al*, 2005). Once the adsorption layer depth is equal or greater than two meters, such an indicator as the minimum necessary deposit volume can be replaced by the minimum mire area (F_t) of 0.005 ha. This means that a mire will not change when 1 m^3 of contaminated water is discharged to a mire area of 0.005 ha or 50m^2. Then one hectare of mire suffices to purify 200 m^3 or 20,000 l water monthly (given a maximum daily outflow volume of 6.45 m^3). If, for instance, the waste concentration is ten times greater than the admissible one, then their daily volume should be reduced to 0.645 m^3.

RESULTS

The cost-effectiveness (E) of the peatland water purification by a mire (Yampolskyet al, 2005) was calculated on the basis of a specific indicator for 1 ha:

$$E = DU$$

Here $U \approx 6.45$ m^3/day/ha is the waste volume purified by 1 ha of a mire for a day, when the contamination level is 1. D is the net financial value ($/$m^3$) from the water purification by a water treatment station when the water has the same level of contamination with suspended substances (mg/l). The cost-effectiveness of the annual effect of the water purification by 1 ha of a mire (E_y) can be obtained as a product of E and T – the outflow time during the warm seasons (210 days). *When the mire is left in its natural state, $E_y \approx 40$ $ for 1h for 1 year.* However, taking account of the gradual accumulation of the contaminants in the mire, the purification effect indicator will gradually decline. Therefore the cost-effectiveness of the total water purification effect (E_{yt}) during many years should be calculated by adding discounted indicators for the calculation period (for example, 30 years). Corrected for the discounting, $E_{yt} \approx 570$ $ for 1ha for 30years (for a discount rate of 6% the discounting factor is 14.21).

However, using naturally wet mires for water purification is not very successful, and its cost-effectiveness is rather modest. In contrast, dry peat is more effective in retaining waste water pollutants due to higher peat adsorption properties. Therefore to use peat adsorption properties more effectively and thereby reduce the area of the mire area needed for purification, it is recommended to drain a peatland, which will also extend the time period of water purification by the mire to the whole year.

Using a part of a dried peatland (peat deposits with a humidity of 84-88%) as purification facilities is based on the following processes and variables: natural aeration, filtration and adsorption capacities of the peat, ion exchange capacity of the peat substrate, vegetable cover generation, microbiological activity growth, freezing and thawing, waste water dilution before flowing into a water receiver. Each of these effects has its own peculiaritieswith complex interrelationships, which determine the process duration (Yampolsky et al, 2005).

Purification of one m^3 household waste water for a year requires five to ten m^3 dry peat deposit as a function of the adsorption properties of the peat. In contrast to the first case, of overland flow over an intact wet peatland, the waste water flows directly through the peat layer, so its volume decreases depending on the adsorptive peat complex (Belkevich &

Chistova, 1979). Underground filtration of a 1 hectare 3-3.5 m thick peatland area can provide the water purification operation time up to 20 years.

A water purification system requires a system of channels feeding the wastes, and a parallel feedback system of receiving drainage channels. The distance between the feeding and receiving channels can change depending on the filtration and adsorption characteristics of the peat, as well as the peat layer thickness. When the filtration rate increases and peat's adsorption properties per a unit time decrease, the distance between the channels (feeding and drying/receiving ones) is increased, and vice versa. When the peat deposit thickness decreases, the distance between the channels is decreased in order to maintain the water filtration rate required.

In waste water filtration calculations, it is substantial to exclude a waste water backflow into the feeding channel. The layer of higher water/solutions flow rates near the water surface is assumed to be 10 cm thick. This layer changes its position during a year as a function of the water surface level. The perimeter of the feeding channels on a mire section is assumed as constant (when the waste water volume feed is stable) and is determined by the following expression:

$U_v = H_f P L_f$ or $P = U_v/(H_f L_f)$,

Here U_v is the daily input waste water volume (100 m^3); H_f is the filtration layer thickness (0.1 m); P is the perimeter of the feeding channel with filtration in both directions from its axis; L_f is the wastes filtration length through low and medium decomposition peats for a day (10 m). Taking into consideration the peat deposit filtration rate (for example, $v_f = 0.1$ m/day), the feeding channel length $L = P/2 = U_v/2H_f\ v_f \approx 6000$ m (for $L_f \approx v_f t$ and t = 1 day). When $v_f = 1.0$ m/day, $L \approx 600$ m; when $v_f = 10$ m/day, $L \approx 60$ m. It is recommended to choose peat deposit sections of $v_f \geq 10$ m/day for practical purposes and calculations. Instead of a single channel, a network of two 30 m-long channels or three 20 m-long channels may be chosen.

Calculating the feeding channel size, the season should be taken into account. Summer features greater open water surface area that increases evaporation and contaminant concentration. These factors can be curbed by using a corrugated pipe covered with a wet peat. In winter, ice can cause a water backup, channel deformation and abnormal filtration flow. That is why the pipe should lie below the freezing level, at least 70 cm deep. Then the channel should be at least 1.0 m deep, whereas the pipe size should be 30 cm or less. If the feeding channel length is, for example, 50 m, then it is to contain up to 100 m^3 a day, with its area equal to 50 m^2 at the depth of 1 m, and the feeding channel width equal to 1 m or less in its middle.

The purification facilities effectiveness is evaluated by comparison between the typical water treatment device BIO-100 and the natural water purification services provided by the dried section of a peat deposit. The cost of the purification facilities construction on a peat deposit is calculated as approximately 80000 \$. The BIO 100 construction cost 260000 \$. Specific capital expenditures for 1 m^3 of purified wastes are 0.13 \$/m^3 and 0.35 \$/m^3 for a peatland area and BIO 100, respectively.

CONCLUSION

Our research shows that peatlands can provide purification facilities to purify waste waters up to the conditions required. As a result, the capital expenditures on the purification facilities construction can be lowered, maintenance cost can decrease, no electric power is required, and resources can be saved.

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