Analysis of the reclamation measures efficiency within watershed and their impact on the water bodies

I V Glazunova ORCID 0000-0003-4931-2008, N P Karpenko ORCID 0000-0001-6638-149X

Russian State Agrarian University-Moscow State Agricultural Academy named after K. A. Timiryazev, Institute of Land Reclamation, Water Management and Construction named after A. N. Kostyakov, Moscow, Russia

E-mail: ivglszunova@mail.ru; npkarpenko@mail.ru

Abstract. The results of the detailed analysis of reclamation measures to improve the quality of water and land resources in the territory of the Sheshma River basin in Tatarstan are given in the paper. The classification of factors affecting the pollution of diffusive runoff coming from agricultural land, as well as measures to reduce water pollution and classification of methods to prevent water pollution of runoff coming from the reclaimed land and rural areas are developed. All methods on water and land quality improvement in the catchment area of the river are divided into 5 groups according to main issues and localization. The efficiency of the above groups of reclamation measures are determined on the base of water management balances including maximum pollution coefficients estimation. The analysis was carried out and the factors influencing the efficiency of the recommended measures on water and land detoxification were recommended. The factors that have the greatest impact on the efficiency of the recommended measures are: the degree of erosion of land resources in the catchment area, reclamation modes, the availability of drainage, the quality of irrigation and drainage waters. Some recommended ranges the recommended measures application are given taking into account hydrogen indicator, texture on soil, drainage flow salinity, contamination of surface runoff from agricultural lands with heavy metals, pesticides, etc.

1. Introduction. The impact of land reclamation on water resources within river catchments has been considered by many Russian and foreign researchers. For example, Afonin, V. V. made a prognostic model of the water balance for the reclaimed river catchments [1]. The solution to the issues of reclamation within watershed area by means of flow-regulating hydraulic engineering was proposed by Mordvintsev M. M. and Omelaev T. Yu. [2]. S. M. Novikov studied the influence of drainage on the hydrological mode of water resources in the reclaimed territories and river basins [3]. Jerzy M. Kupiec, Ryszard Staniszewski, Szymon Jusik [4] studied the impact of agricultural land use in the catchment area on water quality. Katarzyna Oszczapińska, Iwona Skoczkol, and Joanna Szczzykowska studied the impact of anthropogenic activities in the catchment area on water quality [5]. Aliev Zakir Huseyn Oglu investigated the influence of irrigation on the condition of water and land in Azerbaijan [6].

The difference between the presented study and the above mentioned ones is that the water management balances were considered. Our research is based on an integrated approach, the compilation of water management balances and the development of classifications of all types of reclamation measures to provide segregation and structuring of their impact on the water resources.

The cost of materials and work required to construct large structures for water quality improvement...
is constantly increasing, so an alternative solution is to use less expensive, but sufficiently effective local structures, as well as reclamation water protection measures. Therefore more and more attention is paid to such structures as: small local treatment facilities, for example, constructed wetland, settling ponds, absorbing and filtering wells, filtering dams, in supplementation with phytomeliorative and agrotechnical measures, sorbent meliorants’ application to improve the quality of land and water. The use of local structures and land reclamation measures’ application are becoming one of the priority measures land and water resources conservation as well as pure water accumulation in rural areas, which is significant especially under the development of small-land farms in Russia [7].

2. Models and Methods.
Research and analysis of reclamation measures and local structures to prevent and/or to reduce water bodies’ pollution coming from reclaimed lands and rural territories were carried out in accordance with the following approaches:

Classification of factors influencing the intensity of diffuse effluents pollution coming from agricultural land and the efficiency of reclamation measures to reduce land and water resources are presented in the table 1, figure 1.

Table 1-Factors affecting the efficiency of land reclamation measures to improve quality of land and water resources.

| Climatic condition | Soil conditions | Hydrologic conditions | Hydrogeologic conditions | Agrochemical conditions | Agrotechnical conditions | Biological conditions | Land reclamation conditions |
|---------------------|-----------------|-----------------------|--------------------------|-------------------------|--------------------------|------------------------|-----------------------------|
| Precipitation       | Soil type       | Terrain of the catchment area | Water table depth | Fertilizers’ application | Tillage system | Type of agricultural crops | Irrigation method          |
| Evaporation         | Granulometric composition | Catchment area slope | Filtration coefficient | Plant protection | Agricultural machinery | Crop rotation | Water supply intensity |
| Sum of positive temperatures | Humus content | Land use structure in the catchment area | Underground flow rate | Measures of chemical ion | Secondary salinization | Dehumidification | Irrigation standards |
| Water reserves in snow | Exposure to erosion | Aggregation density | Lakes | Means of chemical soil reclamation | Dehumidification rate | Drainage depth | Water supply mode |
| Snowmelt intensity  | Inter-unit coupling | Compaction ratio | Waterlogging | Surface runoff rate | | | |
Figure 1. Measures to reduce water pollution coming from agricultural land with dispersed runoff.

Classification of methods and technologies to prevent water pollution caused by return water from reclaimed land and rural areas is shown in the figure 2 [8, 9].

Figure 2. Classification of reclamation measures to prevent water pollution caused by return water coming from reclaimed land and rural areas.

To estimate the efficiency of land reclamation measures and structures which are used to reduce land and water pollution, water management calculations according to standard formulas were made. The efficiency of the following reclamation measures and structures to improve the quality of land and water resources for the Sheshma River basin in the Republic of Tatastan was taken into account:
- To improve water quality:
  1) local structures on drainage flow treatment;
  2) constructed wetland for treatment of drainage and discharge waters coming from irrigation systems, municipal wastewater and livestock farm wastewater.
  3) measures and techniques on drainage and waste water desalination and demineralization
  4) additional treatment of surface runoff (sorbent ameliorants, phytomelioration, filter shafts, etc.).
  5) ponds and special tanks used for drainage flow and rainwater collecting, storing and re-using.
6) measures and local structures for water treatment directly in the riverbed, for example, riverbed wetlands.

- to improve land quality:
  1) sorption materials application to immobilize pollutants;
  2) plants which are tolerant to pollution and/or salinization of soils;
  3) calculation and/or experimental determination of the total phytotoxicity of the soil under the pollution by various pollutants;
  4) agrochemical reclamation measures to immobilize pollutants in the soil;
  5) high-barrier plants to obtain environmentally friendly products.

Water management balances are calculated for the years of 75% - and 95% - availability on river flow.

The considered reclamation measures are divided into 2 groups according to the main issue and the mechanism of action to improve the quality of land resources in the territory of the Sheshma River catchment.

1) group of agrotechnical and agrochemical measurers.
   2) group of phytomeliorative measurers.

The considered reclamation measures and structures are divided into 3 groups according to the main issue, mechanism of action and localization to improve the quality of water resources in the territory of the Sheshma River catchment.

3) group of reclamation measures and structures to increase treatment efficiency of drainage flow, wastewater from rural settlements and livestock farm.

4) group of reclamation measures and structures to increase the efficiency of treatment of diffuse flow from agricultural (reclaimed) lands.

5) group of reclamation measures and structures to increase self-purification capacity of the river.

3. Results and Discussion

According to the results of classifications, expert assessments and data from water management calculations, the most efficient reclamation measures and structures, which at the same time have a wider range of applications are the following: treatment efficiency increase of: drainage flow, wastewater from rural settlements and wastewater from livestock farms (90% efficiency according to the water quality estimation – the coefficient of maximum contamination).

The second group having high efficiency: treatment of diffuse flow from agricultural (reclaimed) lands. (80% efficiency according to the water quality estimation – the coefficient of maximum contamination).

The third group - agrotechnical and agrochemical measures with an efficiency of 70% in terms of the maximum pollution coefficient (MPC).

The fourth group - measures and structures on increasing the self-purification capacity of the river with an efficiency of 60% according to the MPC.

The fifth group - phytomeliorative measures with an efficiency of 50%. [10, 11, 12]. The results of the calculations are shown in the Figure 3.

Water management equation was calculated according to the well-known formula:

\[
\text{WEB} = W_r + W_{gw} + W_{ret} + \sum W_{ret} - \sum W - W_{exh} - W_{env} - W_{agr} - W_{clim}
\]

where: \(W_r\) - the river stream volume; \(W_{gw}\) - water intakes from underground water; \(\sum W_{ret}\) - return waters; \(W_{ret}\) - water territorial redistribution; \(W_{exh}\) - river flow exhaustion caused by underground water intake; \(\sum W\) - water consumption; \(W_{env}\) - environmental friendly river flow; \(W_{agr}\) - changes in the river flow caused by agricultural activities in the catchment area (it is determined as the difference between the total evaporation for the crops and natural meadows, taking into account the structure of crop rotation [13]); \(W_{clim}\) - change in the river flow caused by global climate change (it is determined as a proportion of natural river flow to the forecast river flow data) [14, 15].
According to the results of the water management balances, there are no water shortages in the Sheshma River basin. Water quality in the Sheshma River without reclamation measures and structures corresponds to the "dirty" class. (table 2, figure 3). Taking into account the efficiency of 5 groups of reclamation measures and structures, the water quality in the river is improved to the "clean" class according to the KMP.

Table 2. Classification of water quality by the indicator of maximum pollution.

| Quality class | Very clean | Clean | Moderately polluted | Polluted | Dirty | Very dirty |
|---------------|------------|-------|----------------------|----------|-------|------------|
| $K_{mp}$      | $-0.8$     | $-0.8 - 0.0$ | $0.0 - 1$ | $1 - 3$ | $3 - 5$ | $> 5$ |

Figure 3. Diagram of the reclamation measures and structures efficiency (the estimations were carried out using the values of the maximum pollution coefficient based on the water management balances calculations for the Sheshma River catchment).

To improve water quality in the Sheshma River the water management calculations take into account 2 groups of measures on land reclamation and 3 groups of measures on water reclamation were carried out.

Land reclamation measures, structures and technologies that are considered in the paper belong to the intellectual property of the authors [16, 17, 18, 19]. They include:
- local structures for drainage flow treatment of: filter wells, removable filter elements, filtering dams, surface runoff absorbers, natural and artificial sorbents, protective filter materials;
- constructed wetlands for drainage flow treatment; livestock, rural municipal waste water purification as well as river flow quality improvement;
- storage ponds for surface and rain runoff accumulation, special tanks - such as: open and closed rainwater storage tanks, filter ponds, evaporation ponds, replaceable modules;
- calculation and placement of guiding, intercepting and filtering shafts and gabion-type dams with fillers made of sorbing materials in order to provide additional treatment of diffuse effluents from agricultural land;
- regulating filtering dams in irrigation channels to increase the efficiency of water distribution and to reduce water losses and the risk of groundwater pollution.

4. Conclusions

1) The analysis, classifications and calculations were carried out, and the factors influencing the efficiency of the recommended reclamation measures and structures aimed at improving the quality of water and land resources were identified. Factors having the greatest impact on the efficiency of the recommended reclamation measures were determined.

2) Some ranges on the reclamation measures application to improve the quality of land and water resources are recommended. The ranges on the land reclamation measures applicability to improve the quality of land resources are recommended depending on the value of the hydrogen index and the mechanical composition of the soil. The ranges on the water reclamation measures applicability to improve the quality of water resources are recommended depending on the salinity of drainage flow, contamination of surface runoff coming from agricultural areas, etc..

3) Sorbent-meliorants application for the immobilization of pollutants in the heavy soils at pH of less than 7.

4) Planting tolerant plants in the light soils with pH of less than 7.

5) Obvious determination of the total phytotoxicity of the soil for heavy soils at pH of less than 7.

6) Agrochemical techniques for the immobilization of pollutants in soils are recommended for all types of soil composition in the entire pH range, both in case of heavy metal contamination and in case of pesticide contamination.

7) High-barrier plants planting to obtain environmentally friendly products on light-weight soils contaminating with heavy metals and / or pesticides at pH of less than 7.

8) Local structures construction to provide drainage flow treatment at its mineralization of less than 2 g / l, to provide livestock waste treatment at contamination with excrement of less than 2-3%, to provide rural wastewater treatment in the case of contamination with biogenic substances and pesticides [20, 21].

9) Measures and technologies on desalination and demineralization of drainage and waste water based on ion-exchange facilities, and sorption at its mineralization of more than 2 g / l at the absence of contamination with excrement and insignificant contamination with biogenic substances, heavy metals and pesticides.

10) Additional surface runoff treatment which comes from reclaimed and other rural areas with the help of filter shafts, agrotechnical measures, etc. in the case of its contamination with biogenic substances, heavy metals and pesticides.

11) The construction of special artificial reservoirs (storage ponds) and tanks to accumulate drainage flow and rainwater in the case of: shortages water, drainage flow contamination with heavy metals, livestock waste water contamination of with excrement and biogenic substances, mineralization of drainage and discharge waters.

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