The Formation of Man-Made Landscape With the Use of Wastes of Mining and Metallurgical Production on the Example of the “Vostochny” Quarry

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Abstract. The paper considers the possibility of providing technical stage of reclamation of developed space of the “Vostochny” quarry used as resultevent – slag rubble. The stages of reclamation of the developed space of quarry were substantiated taking into account the existing transport access to the horizons providing the front of works during reclamation. The ways were worked out to increase technological and economic efficiency of the technical stage of reclamation on account formation of receiving containers for the disposal of industrial waste of high-class hazard at the appropriate stage. For conditions of the “Vostochny” deposit is technical and technological expediency of application of the developed technological schemes of placement of industrial wastes of II-IV classes of danger in a various aggregate state defined.

1. Introduction

A significant number of man-made structures such as worked out quarries, warehouses unconventional ores, dumps of mineralized rocks, waste and waste processing industries was formed in some regions of Russia as a result of intensive development of the mining industry. Accumulation of mining and metallurgical wastes is carried out continuously, at the same time no more than 20% of the generated waste is disposed of annually. The formed quarries and dumps in the process of development of the deposit are of great interest for industrial enterprises as capacities for their waste disposal. Mining production is able to supply to the market not only minerals, but also formed in the process of mining technogenic geo-resources. Today quarries and dumps are used only for storage of wastes of the mining-processing complex according to traditional technology of internal dumps forming. There are no technological schemes allowing to form mining constructions and to place in them industrial wastes of various aggregate state of II-IV classes of danger [1]. The task of integrated development and conservation of the earth's interior can be solved by the formation and use of quarries and dumps as receiving capacities for the placement of various industrial wastes. Increase of reception capacity of mining facilities and expansion of the nomenclature of the placed industrial wastes can be reached as a result of justification of technological schemes of their placement in which means of mechanization of works, volumes and properties of both wastes, and overburden rocks are considered. Implementation of the proposed approach will ensure the implementation of the work in the framework of the technical phase of reclamation.
2. Materials and methods

The main provisions of the proposed approach are based on the existing positive experience of the use of man-made spaces for placing production wastes and materials of their processing in them.

Table 1. Examples of use of the developed spaces of quarries for placement of waste of own and third-party production.

| The name of the deposit, location | Technical solutions for use of man-made tanks |
|----------------------------------|---------------------------------------------|
| **Internal dumping**             |                                             |
| Quarry “Obedinenny”, Verkheuralsk region, Chelyabinsk oblast, Ural F.D | Placement of overburden rocks with the use of railway transport. Parameters of copper-zinc ore mining quarry: depth up to 180 m, dimensions in plan 1500 × 800 m |
| Quarry “Zentralny”, Gaisky region, Orenburg oblast, Privolzhsky F.D | Restoration of the preexisting terrain by filling of the worked out space of the quarry with slag of metallurgical production |
| Quarry “Zapadny”, Magnitogorsk, Chelyabinsk oblast, Ural F.D | The technical stage of reclamation of the first phase was completed, it included the filling of the worked out space with slag rubble, delivery of a potentially fertile soil layer with thickness of 1.2 m and 20-centimeter layer of vegetable soil. |
| Quarry “Alekseevsky”, Ordzhonikidze, Dnepropetrovsk oblast, Ukraine | The polygon for storage and disposal of solid waste consists of two territorial parts: a section for storage of solid waste and a section for placement of household objects. There is a layer-by-layer filling of waste with soil from quarry developments. |
| **External dumping**             |                                             |
| Central storage, Hannover, Germany | The dump has a height of 60-120 m above the natural surface and forms a manmade hilly landscape with four hilltops of about 140 hectares |
| **Placement of the current tailings of concentrating factories on worked out quarries** |                                             |
| Gaisky GOK, quarry No. 2, Orenburg oblast, Privolzhsky F.D | Delivery of the flotation tailings from concentrating factory to the quarry is by filling complex, the consistency of solid : liquid is 1:6.8 to 1:8. A distinctive feature of this quarry is the presence of a drainage drift connecting the quarry with an underground mine and a significant column of excess water over the washed tailings in the almost complete absence of scattered filtration through the sides of the quarry |

Based on the positive experience of PJSC Magnitogorsk Iron and Steel Works on restoration of lands, which were disturbed in the development of the reserves of the deposit “Zapadnoe”, it is decided to implement the technical stage of recultivation at other worked out quarries, which are on the balance of the mine ore mining and processing production. Besides quarry “Zapadny” “Vostochny”, “Walunchatyh rud”, “Podotvalnoe” belong to the territories, which are disturbed by mining operations and must be recultivated. [3] It should be noted, that the realized at the moment technical stage of recultivation of the developed area of the “Zapadny” quarry allowed to reveal prospects of using metallurgical slag for this purpose.

As a result of remelting of iron ore raw materials PJSC MMK produces annually up to 5 million tons of metallurgical slag, which is stored on the earth's surface in the KKZ area. In addition, about 45 million tons of slag have been accumulated in the 2nd and 3rd phases of slag dumps. Storage of metallurgical slag on the surface of the earth is accompanied by significant environmental payments under the law. At the same time, the iron content in slag is from 3 to 24% [4]. As a result of their
recycling the combine partially provides its demand for metallurgical raw materials and also provides the market with additional products in the form of slag crushed stone, sand, raw materials for production of mineral wool and other. However, the percentage of sales of these products does not exceed 15%, in this connection on the one hand there is a need to find places for storage of products of metallurgical slag processing, on the other – there is a need for reclamation of worked out quarries and dumps. Recycling of both old and current slags before their use for the reclamation of the quarry will allow PJSC MMK to get additional raw materials, additionally to reduce the volume of slag dumps on the daily surface and return to the state the restored lands, which were disturbed previously by mining operations.

The implementation of the technical stage of the restoration of the “Vostochny” quarry means the delivery of slag using railway transport and then their movement in the quarry by road transport.

The eastern part of the Magnitogorsk deposit was worked out by “Vostochny” quarry from 1946 to 2006. The absolute mark of the quarry bottom was at the time of the end of mining operations - 330.0 m. Quarry depth is 130 m from conditional mark 460 m, which divides the deep and upland part. At the end of working out the length of the quarry was 2000 m; width-950 m; depth-110 m. The total area of the developed space is 172 hectares. The level of the water in the quarry is 362.71 m on 07.06.2013. Based on the existing conditions, there are two possible options for the implementation of the technical stage of the reclamation of the developed space of the “Vostochny” quarry using as a reclamation (backfilling) material the product of metallurgical slag processing-slag rubble.

Option 1. Delivery of slag rubble will be carried out by road from the dead end № 19 of the “Zapadny” quarry to the south side of the “Vostochny” quarry and unloaded under the slope from the mark 490 m or from the south-west side from the mark 440 m. The distance of transportation of slag rubble will be 3.5 km and 5.8 km respectively.

Option 2. Delivery of slag rubble to the “Vostochny” quarry, the use of railway transport is considered. Moreover, it is planned to unload dump cars directly into the developed space of the quarry.

As a result of the study of the two options, the second option is the most economically expedient, because the cost of slag rubble transportation by rail, taking into account the re-laying of tracks, is twice cheaper than by road. Start of reclamation is provided after the completion of the auxiliary works in formation and planning of railway tracks.

The technical stage of reclamation is conditionally divided into 4 steps. Changes in the direction of the placement of dump rubble during reclamation were taken as a condition of their division.

It is necessary to correctly determine moments of laying of switches and the directions of railway. The first two steps provide backfilling with slag rubble to the technological horizon of previously worked-out quarry:

- the first step – backfilling of the developed space. Formation of a horizontal platform.
- the second step – the transfer of railway in the southern direction of the previously non-recultivated site.

In the next two steps it is planned to create a horizontal platform with mark 430 m in the southern part of the quarry to form the ground for acceptance of industrial waste:

- the third step – backfilling of the recultivated site to the mark of 430 m. The movement of the work front is envisaged in the northern direction. This provides for the formation of five cards, four of them are intended for placement of waste of III class of danger and one for the waste of II class of danger.

- the fourth step - implementation of actions for increase of the absolute mark of the reclamation horizon from 430 m to 445 m is provided for increase of receiving capacity of the developed space of the “Vostochny” quarry and prolongation of terms of acceptance of slag in the quarry. For this purpose it is provided at the fourth step to make unloading of railway cars with slag from a constant deadlock at the movement of the front of works in the southern direction.

So at the first step it is planned to fill the worked out quarry space from the horizon of 430 m with the promotion of the work front to the West. The duration of this step is estimated at 4 years with the
annual progress of the front work in the north-west direction. So unloading of slag rubble from railway cars is provided almost along a straight segment “fig. 1a”.

At the finish of the first step of reclamation is provided the transfer of the railway track in the southern part of previously uncultivated land with the purpose of the organization there of the front of the work and its movement in a southerly direction.

At the beginning of the second step of work it is planned to build cards on the reclaimed area of the ground for the industrial waste disposal of II-IV class of danger with the aim of increasing of economic efficiency of the technical stage of the reclamation of the developed space of the “Vostochny” quarry. To achieve this goal is provided formation of the horizontal surface with the presence of transport access in short time. The optimal location for the landfill is the southern part of the quarry. It is here that it is planned to build cards for the reception of industrial waste. That's why at the end of the second step it is possible to use the card with access through the southern slope or through the northeastern slope on the reclaimed horizon of 430 m “fig 1b”.

Figure 1. Quarry plan at the end of the first (a) and second (b) stages of quarry reclamation.

In accordance with the statistics of metallurgical combines with annual volume of finished products up to 12 million tons there is in the same period waste of the II-IV danger class up to 26 thousand m³. This volume was taken as the unit capacity of one card. The calculation of the parameters of cards for industrial waste disposal was carried out in accordance with the method, where the card is taken as a geometric figure - a truncated pyramid, that's why the volumes of overburden rocks were not taken into account because of corner fillet of the dump [8].

In order to determine the optimal number of cards on a limited area a computer program “Calculation of the dump capacity for industrial waste disposal of the II-IV danger class in the developed space of the quarry” was developed (certificate of registration of the computer program №2013618403). The program interface and simulation results are shown in “fig 2”.

Figure 2. Program interface of the calculation of parameters of cards for industrial waste disposal of the II-IV danger class.
In order to reduce the time of commissioning of selected cards it is provided at first to ensure the implementation of areal dumping and then to complete the formation of dams by peripheral dumping. This technology makes it possible to refuse the use of additional expensive anti-filtration materials, but there are certain requirements for inert rocks, in particular to the filtration coefficient and the technology of their laying. As inert rocks it is envisaged to use the clay from the dumps of the “Podotvalnoe” deposit.

So the construction of the polygon will allow for the fifth year of recultivation of the “Vostochny” quarry to ensure the receiving of industrial waste of the II-IV danger class.

This approach does not contradict the world trends in the field of land restoration. In modern technical and economic conditions mining production is able to supply to the market not only the extracted mineral, but also the mining constructions formed with the set technological properties.

3. Results and Discussion

On the basis of the conducted researches on targeted formation and development of man-made capacities for conditions of a number of quarries in the Ural Federal district is concluded, that the outstripping extraction of loose overburden rocks and their selective storage at the stage of quarry construction allows to use them at recultivation for creation of capacities for the purpose of placement of industrial wastes of II-IV classes of danger.

For conditions of the “Vostochnoe” deposit is technical and technological expediency of application of the developed technological schemes of placement of industrial wastes of II-IV classes of danger in a various aggregate state defined. Development of recommendations on the use of the relevant technological scheme was carried out taking into account the needs of PJSC MMK in placing its own industrial waste “table 2”.

Table 2. Calculated economic effect from the implementation of the recommendations at “Podotvalnoe” deposit (in prices 2017).

| Type of technological scheme | Parameter of cards, m | Number of cards, PCs. | Danger class of industrial waste | Volume of waste, t | Economic effect, thousand rubles. |
|-----------------------------|-----------------------|-----------------------|---------------------------------|------------------|----------------------------------|
| Capacitive                  | A B h                 |                       |                                 |                  |                                  |
| 80 40 10 10 8              | III                   | 95200                 | 73304                           |                  |                                  |
| 80 40 10 10 8              | IV                    | 95200                 | 69496                           |                  |                                  |
| Peripheral                  |                       |                       |                                 |                  |                                  |
| 210 110 10 1              | III                   | 117500                | 85775                           |                  |                                  |
| 210 110 10 1              | IV                    | 117500                | 65688                           |                  |                                  |

So the combination of technological schemes of industrial waste placement, taking into account the quantitative and qualitative characteristics of the developed quarry space, which must be reclaimed, provides the improving of economic efficiency of mining and metallurgical production, reduction of environmental load in the region and complex development of the bowels of the Earth.

4. Conclusion

At the moment PJSC MMK has positive experience at reclamation of the “Zapadny” quarry with using unsold on the market recycled metallurgical slag in the form of slag rubble, which is placed in worked out space, but its capacity is not enough for the project volume of slag utilization. Reclamation works will be completed in 2-3 years. In this regard is the possibility and expediency of placement slag rubble in the worked out space of the “Vostochny” quarry within the framework of the technical stage of reclamation of lands, which were disturbed by mining works, substantiated.

For increase of the economic efficiency of reclamation is the possibility of construction of receiving capacities (cards) for placement of industrial wastes of II-IV classes of danger considered.
In that way use of the recycled waste of metallurgical production at reclamation of lands, which were disturbed by mining works, allows to provide return to the state of the territories, which were exposed of open pit mining, in the shortest terms and with the highest quantitative and qualitative indicators. At the same time are the tasks of the volume reduction of waste formation in the mining and processing productions solved and this makes possible to reduce environmental load in the region and to raise the integrated development of the subsurface area of the Earth.

5. References
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