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Economic Substantiation of a Quarry Usage and an Overburden Dumps, Considering the Disposal of Industrial Waste in them

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Abstract: Economic and mathematical method of calculation of worked-out quarries and overburden dump heap value has been considered in this paper. The worked-out quarries have been formed as capacity for disposal of industrial waste and have been based on determination of technogenic geo-resources value. Volume of these capacities has been taken into consideration as a base of useful qualities of quarries and overburden dumps used in the form of volume for disposal industrial waste. Value of technogenic geo-resources is monetary value of the cost of all useful properties, qualities or components containing in technogenic facilities formed as result of mining activity.

Key words: Value . capacity . overburden dump . industrial waste . cost

INTRODUCTION

Under increasing of world mineral resource consumption volume of worked-out quarries and overburden dump are constantly growing [1, 2]. The world extraction of different minerals is about 25 million ton but the end product of these extractions is only 1-1, 5 million ton (4-6%), the rest is waste [3]. A large amount of waste are produced by enterprises as well.

Artificial construction/design of volume in the earth crust and on its surface is one of the solutions in reduction of waste accumulation [4]. So it is profitable for industrial cities to be located near the worked-out quarries and overburden dump, which are allocated for industrial waste.

Industrial non hazardous wastes with purpose of reclamation are efficient to dispose in the worked-out quarries and the overburden dumps as it exempts completely from environmental payments. Terrain that is damaged with open cast mining is restored and recultivated [5, 6].

Thus issues of economic efficiency of the worked-out quarries and the overburden dumps usage as the volume for industrial waste as well as the base of value technogenic geo-resources have been taken into consideration.

METHODOLOGY

Complex of mathematical methods for compilation of economic laws with technological processing on formation of technogenic geo-resources and disposal industrial waste there, software for statistic analysis, performed by StatSoft company, in which function of analysis, management, extraction and visualization of data with statistic methods are realizing, have been used.

Key part: Economic and mathematical method of calculation of worked-out quarries and overburden dump value that are used as volume for industrial waste disposal and based on value technogenic geo-resources has been offered in this paper.

The overburden dump value, desighned in the form of volume for disposal industrial waste are calculated by the formula

$$Ц_{o-d} = k_P \cdot \sum_{t=1}^{T} V_l \cdot \rho \cdot C_{d.iwasts} \cdot \eta - C_o - C_{i.s} - C_{l.r} - C_{t.s} \quad (1)$$

where $Ц_{o-d}$-overburden dump value, \$; k_P-a share of standard cost for disposal industrial waste in the special landfills and sites (k_P = 0,7); *t*-step of simulation, years(*t*=1, 2,..., T); *T*-period of volume designing, years; η_P-discounting index; ρ-waste density, ton per m^3; $C_{d.i\,wasts.s}$-fee for disposal one ton of i-type wastes in within ascertain limits; V_l-Volume in the body of the dump for disposal waste m^3; C_o-cost of overburden dump construction as volume, \$; $C_{i.s}$-Cost of impervious screen, \$; $C_{l.r}$-environmental cost for location rock refuse, \$; $C_{t.s}$-cost of transportation from the source of waste to dump, constructed in the form of volume, \$.

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$$C_o = \sum_{t=1}^{T}(k_{o.d} \cdot З_{o.d} + З_l) \cdot \eta_t \qquad (2)$$

where $З_{o.d}$ -cost of traditional construction dump/heap, \$; $k_{o.d}$-cost increase on designing constructed dump in the form of volume campared with traditional dump (1,0-1,35%); $З_l$ -outpayment for employed land, \$.

$$З_{o.d} = C_s \cdot V \qquad (3)$$

where C_s-stowage activity cost of one cubic meter rocks, \$.

$$З_l = C_{pay.} \cdot S \qquad (4)$$

where k_{pay}-annual rate payments (tax or rent rate) per 1 hectare of the land, \$; S-area needed for dump designing in the form of volume, hectare.

$$C_{i.s} = \sum_{t=1}^{T}(V_s \cdot (C_s + L_s \cdot C_{t.km} \cdot \rho_s)) \cdot \eta_t \qquad (5)$$

where V_s-the stuff volume needed for impervious screen, m^3; C_s-the laying activity cost of one m^3 impervious screen, \$; L_s-the transport distance of impervious screen stuff, km; ρ_s-density of impervious screen stuff, ton per m^3; $V_{t.km}$-the ton-kilometer cost of transportation from the generation source, \$.

$$C_{i.s} = \sum_{t=1}^{T} V_t \cdot \gamma \cdot C_{d.iwasts} \cdot \eta_t \qquad (6)$$

where V_t-the volume of overburden rocks, m^3; γ-density of overburden rocks, ton per m^3.

$$C_{l.r} = \sum_{t=1}^{T} C_{t.km} \cdot L_t \cdot V_{to} \cdot \rho \cdot \eta_t \qquad (7)$$

where L_t-the distance of waste transportation, km.

Whereas draft maps should be carried out in elicit form on correlation side from 1:1.5 to 1:4 with the purpose of reduction uncovered surface of disposal waste, overburden dump should be designed in rectangular shape. Formulas (5)-(7) allowed to calculate the parameters of single layer dump, the end formula are presented in the following.

$$V = A \cdot B \cdot h + h^2 \cdot ctg\,\alpha(A + B) + 1,33 \cdot h^3 \cdot ctg^2\alpha \qquad (8)$$

where A, B-dump dimension along bottom, m; *h*-dump height, m; α-angle of dump slope, degree.

$$S = \frac{A^2}{K} \qquad (9)$$

where K -interrelation index of side dump bottom.

$$A = \frac{K \cdot \left(h^2 \cdot ctg\alpha \cdot \frac{1+K}{K} + \sqrt{h^4 \cdot ctg^2\alpha \cdot \left(\frac{1+K}{K}\right)^2 - 4\frac{h}{K}\left(\frac{4}{3} \cdot h^3 \cdot ctg^2\alpha - V \cdot K_r\right)} \right)}{2 \cdot h}$$

where K_r -degree of fragmentation rocks.

Costs for disposal wastes in the ecology management limits
under $V_{i\ waste} < V_{l.i\ waste}$

$$C_{i.s} = \sum_{i=1}^{n} C_{d.iwasts} \cdot V_{i\ waste} \qquad (11)$$

where $V_{i\ waste}$-actual disposal waste (ton, m^3), i-type of waste (i = 1, 2,... n); $V_{l.i\ waste}$-annual limit for disposal i-type of waste(ton, m^3).

The cost for over limit disposal of toxiferous and atoxic wastes
under $V_{i\ waste} > V_{l.i\ waste}$

$$З_o = 5\sum_{i=1}^{n} C_{d.iwasts} \cdot (V_{i\ waste} - V_{l.i\ waste}) \qquad (12)$$

where $З_o$ -the cost for over limit disposal of waste \$.

Value of worked out quarries is defined by cost difference for waste storage in the quarries, taken in to account the quarry volume and defined in the following way

$$Ц_{w.q} = k_p \cdot \sum_{t=1}^{T} V_{v.w.k} \cdot \rho \cdot C_{d.iwasts} \cdot \eta - C_1 - C_2 \qquad (13)$$

where $Ц_{w.q}$ -the value of worked out quarry space, \$; $V_{v.w.k}$-the volume of worked out quarry space, m^3; C_1-costs of waste disposal in the quarry space, \$; C_2-costs of the worked out quarry space designing and supportive activities; \$.

$$C_{d.iwasts} = H_{d.iwasts} \cdot K_{e.f.} \qquad (14)$$

where $H_{d.iwasts}$-standard fee for waste disposal, \$ per ton $K_{e.f.}$-coefficient taken account of ecological factors (e.g. such as soil condition) according to the economic regions of the country. For the Nordic countries-$K_{e.f.}$ = 1,7.

$$C_1 = \sum_{t=1}^{T}(3_t + 3_{t.q.} + 3_{f.w.})\cdot\eta_t \quad (15)$$

where 3_t -expenditures of waste transportation from the source to the quarry for disposal; \$; $3_{t.q.}$ -expenditures of waste transportation along the quarry to their place for disposal, \$; $3_{f.w.}$ -expenditures of filling the wastes into the quarry, \$.

$$3_{t.q.} = C_{t.km} \cdot L_{rp} \cdot V_o \cdot \rho \quad (16)$$

where V_o-the waste volume placed in the quarry room during a year, m^3.

$$3_{f.w.} = C_f \cdot V_o \quad (17)$$

where C_f-the cost of one m^3 waste filling, \$.

Suggested economic and mathematical method of calculation of worked-out quarries and overburden dump value help to identify dependency value of this volumes on the period of their designing, on the distance of transpiration and the hazardous waste volume of different type (Fig. 1-6).

Under the calculation of expenditures of waste disposal the following initial data were used (prices of 2013 year)

The volume of waste disposal-3 million ton per year; $C_{t.km1}$-the cost of ton-kilometer transportation of the overburden 25\$; $C_{t.km2}$-the cost of ton-kilometer waste transportation by railway transport, 6\$; C_o-the cost of stockpiling into the dump 1,20 \$ per m^3; γ-density of rocks, 2,3 ton per m^3; ρ-density of wastes, 2,5 ton per m^3; K-coefficient depending on equipped place of storage and its allocation from some facilities, 0.3; n-coefficient of stability factor, 1,2.

Figure 1 and 2 show the results of calculation of worked-out quarries and overburden dump value depending on period of waste disposal of V and IV hazardous class correspondingly the volume of 3 million ton per a year during 10 years, L_{t1} is the transportation distance from the source of waste to the place of disposal them into volume, km; and V_o-is the mass of dis posal waste, thousand tons per a year.

Presented dependences on Fig. 1 and 2 indicate that the value of quarry space has positive importance for industrial waste disposal of V and IV class hazardous wastes whereas value in the body of overburden dump has positive importance for industrial waste disposal of V and higher class hazardous wastes. Value of worked out quarry space as well as value in the body of overburden dump are increasing however distance of waste transportation has a great influence on the cost. For disposal of industrial wastes in the body of overburden dump it is impossible to use only railway transport because the volume of overburden dump will increase and it will be necessary to enlarge the area of dump base. So in this case it is needed transshipment

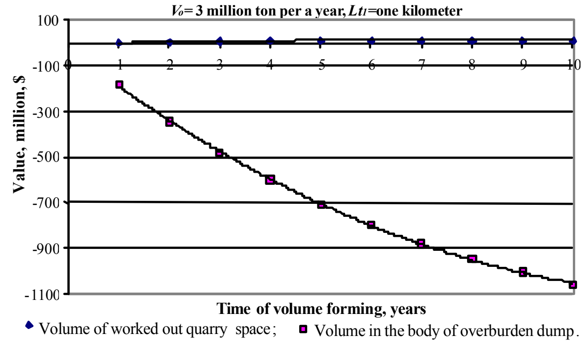

Fig. 1: Value shift of the volume designed in worked out quarry space and overburden dumps depending on the storage time of the V class hazardous waste

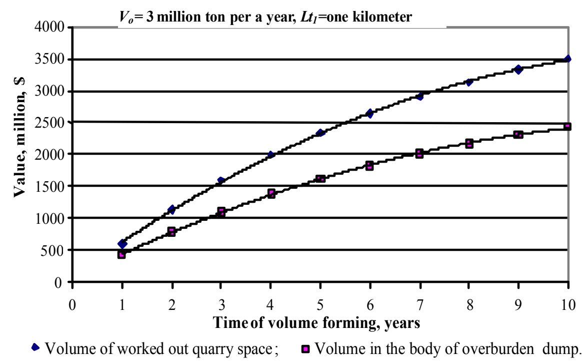

Fig. 2: Value shift of the volume designed in worked out quarries and overburden dump depending on the storage time of the IV class hazardous waste

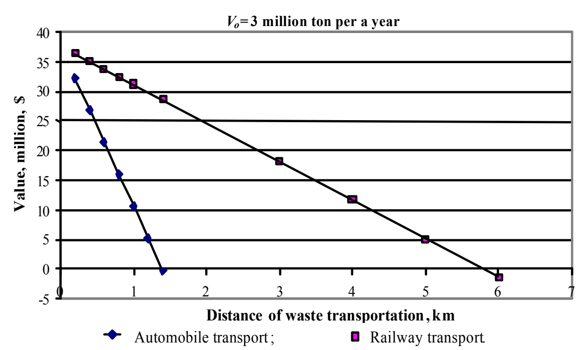

Fig. 3: Value shift of the volume designed in worked out quarries and overburden dump from the distance of the IV hazardous industrial waste transportation

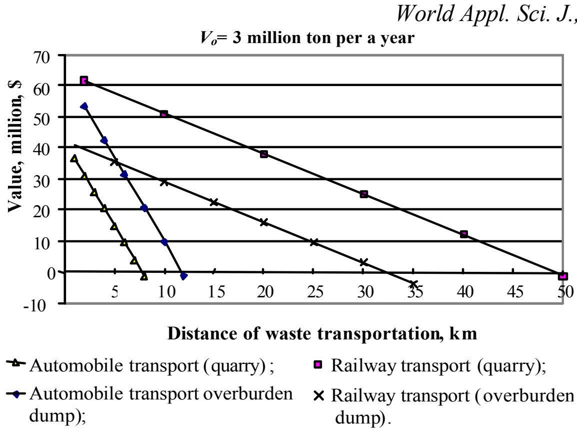

Fig. 4: Value shift of the volume constructed in worked out quarries and overburden dump from the distance of the IV hazardous waste transportation

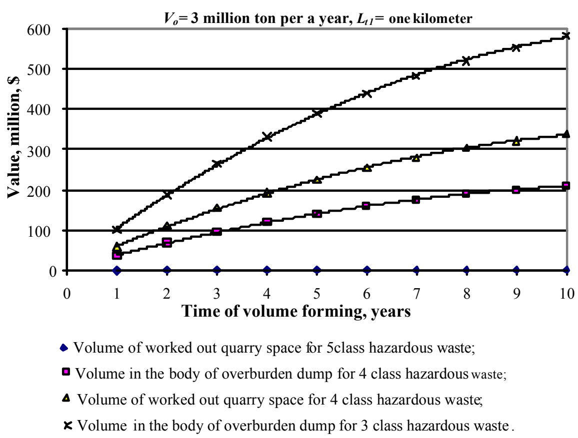

Fig. 5: Value shift of the volume constructed in worked out quarries and overburden dump from the period of storage of the V, IV, III class hazardous waste

from railway transport on automobile transport. Figure 3 and 4 show the value dependences of quarry space and overburden dump on the distance of transportation.

Figure 3 and 4 point out that value shift of the volume constructed in worked out quarries and overburden dump from the distance of the IV class hazardous waste transportation is lower, when the distance of transportation is longer. At waste disposal of V class hazardous waste in the worked out quarries the effective distance of transportation shouldn't exceed 1,5 ? 6 km of automobile and railway means of transport correspondingly. However at disposal of the IV class hazardous waste effective distance for automobile transport is increasing up to 12 km and 7 km correspondingly and for rail way transport is 48 km and 32 km correspondingly. Inefficiency of usage the

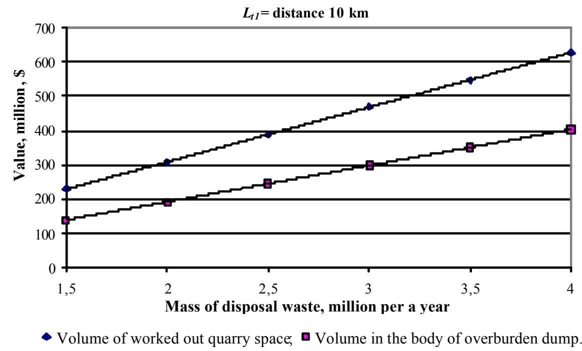

Fig. 6: Value shift of the volume constructed in worked out quarries and overburden dump from the waste volume of IV class hazardous

dump for V hazardous class is accounted for high cost of transport service, nevertheless in case of agreement between owner of the waste about of the part transport compensation economic efficiency of transportation could be increased up to1-1.5 km.

As it is presented on the Fig. 5 the value shift of the volume constructed in worked out quarries and overburden dump from the period of storage depends on the class of disposal hazardous waste. While increasing the class of disposal hazardous waste from V up to IV class the value is increasing 30 times and from the IV up to the III class this increase is doubled.

Data dependence on Fig. 6 shows that at increasing annual bulk of the IVth class hazardous disposal waste the value of worked out quarries and overburden dump is rising. It is explained with high rate of payment for disposal one ton of waste.

CONCLUSION

Suggested economic and mathematical method of calculation for value determination of worked-out quarries and overburden dump, constructed in the form of volume for disposal industrial wastes permit to estimate the expediency of usage them. The value of worked-out quarries and overburden dumps, used as volume for disposal wastes are estimated by the following factors:

1) For the worked-out quarry space: volume, distance of transportation, class of hazardous wastes, time of their storage, costs of supportive activities providing disposal wastes;
2) For overburden dump, constructed as volume: capacity, distance of transportation, class of hazardous wastes, time of their storage, physics and mechanical properties of overburden rocks.

3) To achieve maximum economic effect of worked-out quarries and overburden dump usage constructed in the form of volume for disposal industrial wastes it is necessary to provide this area with railway traffic with the purpose of transport cost reduction and to minimize the cost of worked-out quarries and overburden dump reconstructions into the volume for industrial wastes.

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