The International Journal of
TRANSPORT & LOGISTICS
Međunarodni časopis
TRANSPORT I LOGISTIKA

UDC: 622.68:622.85

ECOLOGY-ECONOMIC ESTIMATION OF OPEN PIT MINE TRANSPORT COMPLEXES IN THE DIFFERENT OPERATION CONDITIONS

EKOLOŠKO-EKONOMSKA PROCENA TRANSPORTNIH KOMPLEKSA POVRŠINSKOG KOPA U RAZLIČITIM USLOVIMA RADA

Olga SHESHKO
Moscow State Mining University, Department of "Nature utilization", Russia

Abstract: *For detection of effect of a type and technical condition of transport equipment, operational modes, condition of the communications, climatic conditions on parameters of a dust content and gas condition of opencast mine the ecology-economic model of calculations taking into account the consequences of exploitation of transport complexes is offered.*

Key words: *transport equipment, dust content, gas condition, ecology-economic model.*

Apstrakt: *U cilju otkrivanja dejstva (uticaja) vrste i tehničkog stanja prevozne opreme, režima rada, stanje komunikacija, klimatskih uslova na parametre sadržaja prašine i gasonosnost u površinskom rudniku, ponuđen je ekološko-ekonomični model proračuna, uzimajući u obzir posledice eksploatacije transportnih kompleksa.*

Ključne reči: *prevozna oprema, sadržaj prašine, gasonosnost, ekološko-ekonomski model.*

1 INTRODUCTION

Now influence of mining on an environment has such influence as direct operation of enterprise. In the Russian Federation more than 200 open cast mines operate concerning output of ore, coal, diamonds, mining and chemical materials etc., and also about 4000 - concerning output of raw materials for building [1].

Therefore complex estimation and forecasting of an environment effect of complexes of machinery must become one of the priority directions of designing and exploitation of enterprises. One of the most labour-consuming, nature - consuming and expensive processes at an open cast mine is the transportation of mined rock. The advance in this area in a large degree determines economy and ecology of a mining enterprise.

1 UVOD

Danas se uticaj rudarske industrije na životnu sredinu ogleda kao direktna posledica rada preduzeća. U Ruskoj Federaciji, više od 200 površinskih rudnika daje rudu, dijamante, rudarske i hemijske materijale itd, a oko 4000 rudnika – građevinske sirovine. [1].

Stoga, složena procena i predviđanje uticaja kompleksa mašina na životnu sredinu mora biti jedan od prioritetnih pravaca u projektovanju i ekploataciji preduzeća. Jedan od najskupljih procesa, u kome se najviše troši rad i priroda jeste prevoz iskopanog kamenja. Napredak otkopa u ovoj oblasti u velikoj meri određuje ekonomsku i ekološku politiku rudaraskog preduzeća.

The mathematical model of calculation of the ecological and economic consequences of exploitation of transport complexes was elaborated with the purpose of the exposure of influence of power of transport equipment, type, carring capacity and technical condition of the equipment, regimes of their work, condition of the transport communications and parameters of a route, and also climatic conditions on parameters of a dust and gas content of open cast mines and adjacent territories.

2 MATHEMATICAL MODEL OF ECONOMIC AND ECOLOGICAL CONSEQUENCES OF UTILITY OF DIFFERENT TRANSPORT COMPLEXES

The mathematical model takes into account a large quantity of the technological and technical factors and allows to receive the values of the results of ecological consequences of utility of different transport complexes for the concrete operation conditions.

Utility of the mathematical model allows to forecast an ecological situation when exploiting transport complex and, varing the possible types of equipment, to avoid above permitted emissions and concentration of harmful matters, providing for an necessary minimum of costs when exploiting the transport of an enterprise. [1,3]

The minimum of general costs at the transport complex is selected as the criterion in the model, and the limitations are represented as the requirements to an environment (according to two complex indexes characterizing maximum emissions).

The calculations of emissions of harmful matters when exploiting transport complexes are made in accordance of specific indexes taking into account technical and technological factors, and also operational regimes. [2]

Masses of emissions of harmful matters from burning in engines of tractive aggregates, diesel locomotives, dump-body trucks

$$M_i = \sum_{k=1}^{k} q_{ik} t_k N k_1 k_t \text{, } kg/day, \quad (1)$$

Izrađen je matematički model proračuna ekoloških i ekonomskih posledica eksploatacije transportnih kompleksa sa ciljem izlaganja uticaja energije prevozne opreme, vrste, kapaciteta nosivosti i tehničkog stanja opreme, režima njihovog rada, stanja prevozne komunikacije i parametara trase, kao i klimatskih uslova na parametre sadržaja prašine i gasa u površinskim rudnicima i okolnom području.

2 MATEMATIČKI MODEL EKONOMSKIH I EKOLOŠKIH POSLEDICA KORIŠĆENJA RAZLIČITIH TRANSPORTNIH KOMPLEKSA

Matematički model uzima u obzir veliku količinu tehnoloških i tehničkih faktora i omogućava da se dobiju vrednosti rezultata ekoloških posledica korišćenja različitih transportnih kompleksa za konkretne uslove rada.

Korišćenje matematičkog modela omogućava da se predvidi ekološka situacija prilikom upotrebe transportnog kompleksa i, prema vrsti opreme, da se spreči da pređu dozvoljenu granicu emisija i koncentracija štetnih materija, imajući u vidu neophodni minimum troškova prilikom korišćenja transporta u preduzeću. [1,3]

Minimum opštih trooškova u prevoznom kompleksu izabran je kao kriterijum u modelu, a ograničenja su predstavljena kao zahtevi za zaštitu životne okoline (prema indeksima za dva kompleksa, koji karakterišu mimalne emisije).

Proračuni emisija štetnih materija prilikom koiršćenja transportnih kompleksa vrše se u skladu sa specifičnim indeksima, pri tom uzimajući u obzir tehničke i tehnološke faktore, ali i režim rada. [2]

Mase emisija štetnih materija iz procesa sagorevanja u motorima vučnih agregata, dizel-lokomotiva, kamiona-dampera.

$$M_i = \sum_{k=1}^{k} q_{ik} t_k N k_1 k_t \text{, } kg/dan, \quad (1)$$

where q_{ik} - specific emission of harmful matter (i) at the regime of work (k), kg/h
t_k - an operating time at the regime of work, h
N - number of the working equipment,
k_t and k_l - coefficients taking into account climatic conditions and technical condition of a park of machines correspondingly.

Maximum single emission of harmful matter:

$$M_{ip}=M_i/(24.3,6),\ g/s \quad (2)$$

Mass of emissions of harmful matters which are blown off from a surface of a transported material, composes:

$$M_{em}=3,6q_{sb}\ F\ Nn_t t_m K_1 K_2,\ kg/day \quad (3)$$

where q_{sb} - specific blowing off solid particles from $1m^3$ of a surface of mining mass, g/m^3s;
F - area of a surface of transported material at the one installation, m^2;
N - quantity of the installations;
n_t - number of trips of the transported mean per day (for the conveyors is equal 1);
t_m - average duration of movement with a load for one trip (for the conveyors time of movement with a load per day), h;
K_1 - coefficient taking into account speed of blowing round of a material (when changing of a speed of blowing round from 2 up to 15 m/s is increased from 1 up to 1,8);
K_2 - coefficient taking into account humidity of a material (at the humidity up to 0,5% is equal 2, at 10% - 0,2, more than 10 % - 0,1).

Masses of maximum single emission from a surface of transported material

$$M_{em}=q_{sb}F\ N\ n_{th}\ t_m K_1 K_2,\ g/s, \quad (4)$$

where n_t - the number of trips of the transported mean per hour (for conveyors is equal 1);
t_m - average time of the movement with a load for one trip, h (for conveyors is equal 1).

gde je q_{ik} - specifična emisija štetnih materija (i) u režimu rada (k), kg/h
t_k - vreme eksploatacije u režimu rada, h
N- broj radne opreme,
k_t i k_l - koeficijenti koji uzimaju u obzir klimatske uslove odnosno tehničko stanje voznog (mašinskog) parka.

Maksimum jedna emisija štetnih materija:

$$M_{ip}=M_i/(24.3,6),\ g/s \quad (2)$$

Masa emisija štetnih materija koje su oduvane sa površine transportovanog materijala, sastoji se od:

$$M_{em}=3,6q_{sb}\ F\ Nn_t t_m K_1 K_2,\ kg/dan \quad (3)$$

gde je q_{sb} – specifično oduvavanje čvrstih čestica sa $1m^3$ površine rudne mase, g/m^3s;
F – oblast površine transportovanog materijala kod jednog postrojenja, m^2;
N – količina postrojenja;
n_t - broj puta koji prevozno sredstvo pređe na dan (za transportere je jednako 1);
t_m - prosečno trajanje pokreta sa opterećenjem za jedan put (za transportere vreme kretanja sa opterećenjem na dan), h;
K_1 – koeficijent, uzimajući u obzir brzinu raspršivanja materijala (prilikom menjanja brzine raspršivanja od 2 do 15 m/s, povećan je sa 1 do 1,8);
K_2 – koeficijent koji uzima u obzir vlažnost materijala (pri vlažnosti do 0,5% koeficijent je 2, pri10% - 0,2, više od 10% - 0,1).

Mase maksimum jedne emisije sa površine transportovanog materijala

$$M_{em}=q_{sb}F\ N\ n_{th}\ t_m K_1 K_2,\ g/s, \quad (4)$$

gde je n_t – broj puta koji prevozno sredstvo pređe na dan (za transportere je jednako 1);
t_m - prosečno vreme kretanja za opterećenjem za jedan put, h (za transportere je 1).

A dust formation on roads has large meaning when dump-body tracks move. Masses of daily formation of a dust during a snow cover is absent

$$M_d = 2(q_{st} K_3 L_t + q_{sf} K_3 L_f) n_t N, kg/day, \quad (5)$$

where q_{st}, q_{sf} - average specific dust formation when one dump-body track covers 1 km of a temporary and fixed road correspondingly, kg / km

K_3 - coefficient taking into account average speed of the movement of dump-body tracks in an open cast mine (when the speed changes from 5 up to 30 km/h is increased from 0,6 up to 3.5) [2,5]

L_t, L_f - the length of a temporary and a fixed road, *km*

n_t - number of trips of dump-body truck per day.

Maximum single emission of dust when dump-body truck moves

$$M_{np} = 2(q_{st} K_3 L_t + q_{sf} K_3 L_f) n_{th} N/ 3,6, g/s, \quad (6)$$

where n_{th} - number of trips of the mean of transport per hour.

The places of reloading of mining rock are also the hotbeds of harmful matters. Masses of emission of solid particles at the reloading points

$$M_{ol} = q_s Q_{ol} K1K2K3K4, t/day, \quad (7)$$

where q_s - specific emission of solid particles of a transferred material, *g/t*

Q_{ol} - quantity of a transferred material per day, *t/day;*

K_3 - coefficient taking into account a height of falling of a material (at the height of falling 0.5 m the coefficient K_3 is equal 0,4, and at 10m -2,5)

K_4 - coefficient taking into account local conditions (a degree of the protection of a place of reloading is changed from 0,5 - 1)

Maximum single emission of solid particles at the reloading points

$$M_{se} = q_s Q \div K1K2K3K4 / 3600, g/s, \quad (8)$$

where Q_h - capacity of a reloading point, t/h.

Stvaranje prašine na putevima ima veliki značaj prilikom kretanja kamiona-istresača. Nema dnevnog stvaranja prašine za vreme snežnog pokrivača

$$M_d = 2(q_{st} K_3 L_t + q_{sf} K_3 L_f) n_t N, kg/dan, \quad (5)$$

gde je q_{st}, q_{sf} – prosečno specifično stvaranje prašine kada jedan kamion istovarivač pokriva 1 km privremene odnosno fiksirane trase, kg / km

K_3 – koeficijent koji uzima u obzir brzinu kretanja kamiona istresača u rudnika sa površinskom eksploatacijom (kada se promena brzine od 5 do 30 km/h poveća sa 0,6 na 3.5) [2,5]

L_t, L_f – dužina privremene i fiksne trase, *km*

n_t - broj tura kamiona istresača na dan

Maksimum jedna emisija prašine prilikom kretanja kamiona-istresača

$$M_{np} = 2(q_{st} K_3 L_t + q_{sf} K_3 L_f) n_{th} N/ 3,6, g/s, \quad (6)$$

gde je n_{th} – broj tura prevoznog sredstva na dan.

Mesta pretovara iskopanog stenja su takođe rasadnici štetnih materija. Mase emisije čvrstih čestica na pretovarnim mestima

$$M_{ol} = q_s Q_{ol} K1K2K3K4, t/dan, \quad (7)$$

gde je q_s – specifična emisija čvrstih čestica materijala koji se prenosi, *g/t*

Q_{ol} - dnevna količina materijala koji se prenosi, *t/dan;*

K_3 – koeficijent uzimajući u obzir visinu sa koje pada materijal (pri visini padanja od 0.5 m koeficijent K_3 je 0,4, a na 10m -2,5)

K_4 – koeficijent uzimajući u obzir lokalne uslove (stepen zaštite mesta pretovara je promenjen sa 0,5 na 1)

Maksimalna jedna emisija čvrstih čestica na pretovarnim mestima

$$M_{se} = q_s Q \div K1K2K3K4 / 3600, g/s, \quad (8)$$

gde je Q_h – kapacitet pretovarnog mesta, t/h.

Taking into account the different intensity level of emission of harmful components in a different time of a year (for the conditions of permafrost in a cold period $K_l = 1$; in a warm period $K_l = 0,3\text{-}0,4$); efficiency of suppression of harmful matters from every source of emission (for example, roads suppression of dust by water reduces emission of dust at 65-90 of%, and by binding materials - at 90-98%, the catalytic neutralizators reduce emission of oxide of carbon-at 75%, hydrocarbon-at 70%, the catalytic neutralizators of double-acting essentially neutralize nitrous oxides etc.); a simultaneity of their emission (for example, the possibility of simultaneous maximum single emission of dust from wheels of dump-body truck accounts for 20%, and emission of carbon and nitrogen - 60%) and a number of other factors, masses of harmful matters (M_i^1) are corrected according to the formulas (1) - (8) and their concentration in a working area is determined

$$C_i = M_i^1 / Q, mg / m^3 .$$

Quantity of air Q in an open cast mine is determined taking into account ventilation plans, wind speed at a surface of open cast mine, temperature of air at the bottom and the surface of open cast mine, depth and its parameters.

The complex index of an air condition with the contents of several harmful matters of monodirected operation $\sum_{i=1}^{i} C_i / LPK_i \le A$ is calculated as for maximum single concentration, and for average daily concentration.

The value «A» represents a supposed share of an air pollution by means of transport for the given open cast mine.

The necessary condition, as was mentioned is the minimization of costs at the acquisition of the equipment (as technological, and reducing negative environment effect), its exploitation, payments for violation of the established standards of nature utilization etc.

$$\sum_{k=1}^{k} S_K \to \min$$

where S_k - element of costs *(k), rub.*

S obzirom na različit nivo intenziteta emisije štetnih komponenata u različito doba godine (za uslove večitog leda u hladnom periodu $K_l = 1$; u toplom periodu $K_l = 0,3\text{-}0,4$); efikasnost suzbijanja (izbacivanja) štetnih materija iz bilo kakvog izvora emisije (na primer, suzbijanje vodom prašine na putevima smanjuje emisiju prašine 65-90 od %, a vezivnim materijalima - na 90-98%, katalitički neutralizatori smanjuju emisiju ugljen-oksida na 75%, ugljovodonika – na 70%, katalitički neutralizatori dvostrukog delovanja prvenstveno neutrališu azotne okside itd.); istovremenost njihove emisije (na primer, mogućnost istovremene maksimalne jedne emisije prašine sa točkova kamiona-istresača obuhvata 20%, a emisije ugljenika i azota - 60%) i određeni broj drugih faktora, mase štetnih materija (M_i^1) ispravljeni su prema sledećim formulama (1) - (8) a njihova koncentracija u radnom okruženju je određena na sledeći način

$$C_i = M_i^1 / Q, mg / m^3 .$$

Količina vazduha Q u površinskom rudniku se određuje tako što se uzmu u obzir depresijske mape, brzina vetra na površini površinskog rudnika, temperatura vazduha na dnu i na površini površinskog rudnika, dubina i njeni parametri.

Indeks klimatizacije u kompleksu sa elementima nekih štetnih materija jednosmerne operacije $\sum_{i=1}^{i} C_i / LPK_i \le A$ izračunava se u pogledu maksimalne pojedinačne koncentracije i u pogledu prosečne dnevne koncentracije.

Vrednost «A» predstavlja pretpostavljeni udeo zagađenja vazduha putem usled rada prevoznih sredstava za dati površinski rudnika.

Potrebni uslov, kao što navedeno, jeste minimizacija troškova pri kupovini opreme (kako tehnološkog tako i smanjenog negativnog uticaja na životnu sredinu), njegova ekploatacija, plaćanja za narušavanje utvrđenih standarda o korišćenju prirode itd.

$$\sum_{k=1}^{k} S_K \to \min$$

gde je S_k – element troškova *(k), rub.*

The calculations were made according to the offered model. They illustrate an air pollution by automobile transport, as the most widespread at an open cast mine.

The calculations were conducted for conditional open cast mine with depth ~ 250m, in which the work of dump-body trucks of the type BEIAZ - 7548 (42 t) with the quantity 20 units for supporting the productivity 10 mln t/year is supposed. According to the industrial necessity after 6 years (term of service of dump-body truck) the replacement of a complex of the type BEIAZ - 7548 at the more powerful complex of dump-body trucks of the type BEIAZ - 7549 (80 t) with the quantity 14 units is supposed.

The calculations have shown that the supposed replacement is not rational and worsens practically all ecological parameters in an open cast mine at 10 - 40 %, and both complex indexes of operation of harmful matters ($\sum_{i=1}^{i} C_i / LPK_i \leq A$) - at 20-25%, though they are brought nearer to its limiting value (0,5) in the first case.

At the same time the automobile transport is rather material consuming, actively consumes deficit kinds of resources: fuel, tyres, spare parts, has high metal consumption (coefficient of tare of modern dump-body truck is equal 0,8 - 0,9). Energy consumption of automobile transport is also great. Labour consumption of technical service and repair is also significant. [4].

3 CONCLUSION

The comparison of the variant of an automobile complex which received the best parameters $\sum_{i=1}^{i} C_i / LPK_i$ and automobile - conveyor complex for analogy conditions illustrates not only sharp reduction of harmful matters, but also decrease of costs, i.e. the share of a new source of air pollution - a reloading complex, isn't significant.

Thus, the calculations have shown that the widely applicable automobile transport reduces efficiency of work of enterprise and makes impossible further increase of depth of an open cast mine.

Proračuni su izvršeni prema ponuđenom modelu. Oni prikazuju zagađenje vazduha putem automobilskog transporta, kao najraširenijoj vrsti zagađenja u površinskom rudniku.

Izračunavanja su izvedena za uslovni površinski rudnik dubine ~ 250m, gde se pretpostavlja da rade kamioni-istresači tipa BEIAZ - 7548 (42t) sa količinom od 20 jedinica za podržavanje produktivnosti od 10 miliona tona godišnje. Prema industrijskoj potrebi, nakon 6 godina (vek korišćenja kamiona istresača) predviđa se zamena kompleksa tipa BEIAZ - 7548 na snažnijem kompleksu kamiona-istresača tipa BEIAZ - 7549 (80 t) količinom od 14 jedinica.

Proračuni pokazuju da pretpostavljena zamena nije racionalna i praktično sve ekološke parametre prikazuje gorim nego što jesu u površinskom rudniku na 10 - 40 %, a oba indeksa kompleksa kod dejstva štetnih materija ($\sum_{i=1}^{i} C_i / LPK_i \leq A$) - na 20-25 %, iako su u prvom slučaju bliži graničnoj vrednosti (0,5).

U isto vreme automobilski transport je veliki potrošač materijala, aktivno troši razne vrste materija: gorivo, gume, rezervne delove, veliki je potrošač metala (koeficijent tare modernog kamiona-istresača je 0,8 - 0,9). Takođe je veoma velika potrošnja energije kod automobilskog transporta. Potrošnja rada kod tehničkog servisa i popravke je takođe značajna. [4].

3 ZAKLJUČAK

Poređenje varijante sa automobilskim kompleskom koja je dobila najbolje parametre $\sum_{i=1}^{i} C_i / LPK_i$ i automobilsko -transporterskog kompleksa za iste uslove pokazuje ne samo znatnu redukciju štetnih materija, već i smanjenje troškova, odnosno udeo novog izvora zagađenja vazduha - pretovarnog kompleksa, nije izražen.

Tako, izračunavanja su pokazala da široko primenljiv automobilski transport smanjuje efikasnost rada preduzeća i onemogućava dalje povećanje dubine površinskog rudnika.

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Reviewal / Recenzija: prof. dr Miloš Grujić