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Research on Rainfall Infiltration Regime into the Waste Dumps Body from Mining Basin Motru

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Abstract. The rock dumps from Motru mining basin are built with sterile material derived from lignite open pits. The mixture of stored rock is heterogeneous, both vertically and horizontally. If to this heterogeneous are added the particle size variations of excavated material or moisture variations of stored rocks, especially in weather conditions with heavy rain, the rock dumps have a totally uncontrollable behavior. The papers objectives are to determine water infiltration regime of the dumps body and of the amount of infiltrated water. For this purpose, is presented pluviometric and temperature regime from Motru region and determination of the parameters characterizing the regime of water infiltration into the rock dumps body by using Horton and SINTACS methods. The results obtained from research works show that in this case occurs the infiltration with accumulation of water, which creates areas with high hydrostatic pressure, with adversely effects on stability of rock dumps..

Keywords: water infiltration, sterile dumps, water pressure.

1. Hydrometeorological Regime of the Area

Located in southwestern territory, in the Getic hills and orographic sheltered in the north and west by the Carpathian mountain chain, we appreciate that the Motru enjoy a temperate continental moderate climate. Rainfall is relatively high, with average annual amounts ranging from 746-906 l/m^2, but they can overcome up to 1180-1330 l/m^2, or decrease to 430-580 l/m^2. Maximum amounts of precipitation fell in 24 hours can sometimes exceed in appreciable quantities the average monthly. Thus, in Tg. Jiu in September 1968 there were 93.6 l/m^2 rain fell in 24 hours, the amount exceeded the 43.8 average l/m^2 monthly averages. At Apa Neagra, in July 1969 rainfall have totaled 154.2 l/m^2 within 24 hours, the monthly average being of 83.2 l/m^2, and finally, at Matasari in July 1991, within 24 hours, 80.0 l/m^2 fell, with 25.8 l/m^2 more than average in July. Snow lasts on average 46-57 days annually, and its thickness can reach averages of 14-72 cm for different decades. Figure 1 presents are annual and monthly average precipitation and temperatures measured at weather station Tg. Jiu, period 1983 - 2006, compared to the corresponding multi hydrological measurement, period 1901 - 2006 and the variation in annual averages for that period can be observed.

From the data emerges as a first conclusion that in the last 10 years of observations, mean values exceeded or reaching interannual rainfall and temperature are relatively common, in eight years for rainfall and eight years temperature. High values of annual average rainfall were recorded mainly in 2004 and 2005 (1007.3 respectively 1121.9 mm than the multiannual average of 726.3 mm), leading to accumulation by infiltration of large quantities of water in the body of waste dumps, such being created favorable premises for triggering landslides [3]. It states that in 2004, in July and November were exceeded the monthly averages rainfall of over two times, and in July 2005 exceeded the monthly average of 3.9 times.

2. Determination of infiltration

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Field tests conducted concluded that the main source of water from waste dumps body comes from rain, without being excluded the possible infiltration from and from within the natural slopes in the area.

2.1. Hortonian mechanism

During rainfall, infiltration potential intensity decreases with increasing ground moisture. If rain intensity remains higher than the potential infiltration, infiltration occurs after the function $f^*(t)$ until the end of rain. This is the case where precipitation is very intense or land has high initial moisture. If rain intensity is lower than the top potential infiltration, initial infiltration, which is equal to the intensity of rain, penetrates the ground until the moment t_r when potential infiltration is equal to the intensity of rainfall and then shallow flow begins. In that moment t_r, cumulative infiltration $F(t_r)$ is equal to the height of the precipitation $h(tr)$. After the moment t_r until the rain intensity becomes again smaller than the potential infiltration, net rain intensity is the difference between rainfall intensity and infiltration potential.

Horton's laws (1940) of potential and relative cumulated infiltration:

$$f^*(t) = f_\infty^* + \left(f_i^* - f_\infty^*\right)e^{-kt}$$

$$F^*(t) = f_\infty^* t + \frac{f_i^* - f_\infty^*}{k}\left(1 - e^{-kt}\right)$$

where:

f_i^* - initial potential infiltration;

f_∞^* - limit infiltration for saturated soil;

k - parameter that defines the potential infiltration rate reduction.

Horton's law parameters depend on soil characteristics. Values proposed by ASCE Manual (American Society of Civil Engineers) [1] are shown in Table 1 and the values proposed in the model recommended by ILLUDAS (The Illinois Urban Area drainage simulation) [5] are shown in table 2. Table 3 presents the classification of land after the Soil Conservation Service.

Table 1 A Horton's formula parameters (A.S.C.E.)

Function type	f_i^*	f_∞^*	k
	(mm/h)	**(mm/h)**	**(h^{-1})**
increased (highly permeable soils)	117	17	5,34
standard (medium permeable soils)	76	13	4,14
low (low permeability soils)	76	6	4,14

Table 2 Horton's formula parameters (ILLUDAS)

Soil group	f_i^* **(mm/h)**	f_∞^* **(mm/h)**	k **(h^{-1})**
A	250	25	2
B	200	12,5	2
C	125	6,5	2
D	75	2,5	2

Table 3 SCS-CN method: soil classification by Soil Conservation Service (SCS, 1968)

Group	**Description**
A	*Very low flow potential*: coarse sands with small content of dust and clay, gravel, very permeable
B	*Moderately reduced flow potential*: most of the sandy soils coarse less, but with high infiltration and saturation capacity

C	*Moderately high flow potential*: fine soil with a high content of clay and colloids, but lower than those in group D. they have a reduced capacity of infiltration and saturation.
D	*Very high flow potential*: most of the clays with high swelling capacity, but also thin soil horizons that form near the surface almost impervious land.

As described in table 3, the mixture of material from the waste dump of Rosiuta quarry fall in groups C and D. In terms of terrain features from waste dumps EMC Motru, respectively land with low permeability (groups C and D classification Soil Conservation Service) from calculations made by the methodology (table 4) were obtained two types of curves for potential and relative cumulative infiltration (figures 2 and 3), in terms of occurrence of precipitation lasting eight hours and a higher intensity than the potential infiltration.

Table 4 Calculation of the potential and relative cumulative infiltration

t (h)	f*(t) (mm/h)		F*(t) (mm)	
	ASCE	ILLUDAS	ASCE	ILLUDAS
0	76.00	125.00	0.00	0.00
0.5	14.83	50.09	17.77	40.70
1	7.11	22.54	22.64	57.73
1.5	6.14	12.40	25.87	66.05
2	6.02	8.67	28.90	71.16
3	6.00	6.79	34.91	78.60
4	6.00	6.54	40.91	85.23
6	6.00	6.50	52.91	98.25
8	6.00	6.50	64.91	111.25

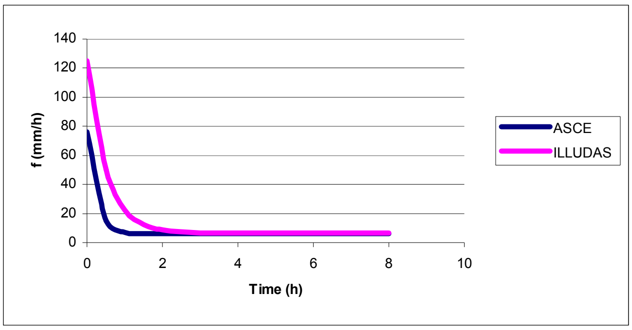

Fig. 2 Waste dump's terrains potential infiltration

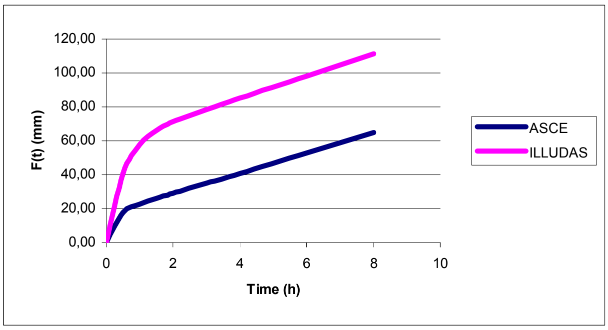

Fig. 3 Relative cumulated infiltration on waste dump

Analyzing the potential infiltration curve is observed that is a reduced curve by ASCE method and corresponding to groups C and D according to the ILLUDAS method. Water infiltration is greatest in the first hours after the start of precipitation, then decreases asymptotically tending to zero and corresponds to long-term precipitation conditions, accumulation of water are formed on the dumps surface. Regarding the relative cumulated infiltration, it increases sharply in the first hours after the start of the phenomenon of precipitation and relatively slow in the next hours. Infiltration process can continue as long as surface moisture decreases on account of the occurrence of internal drainage and evapotranspiration.

2.2. SINTACS method

Basic information needed to evaluate effective infiltration are the historical hydrometrics and thermo series, for an observation period of at least 20 years on the monthly average recorded in all stations located within and near the area of study [2]. Monthly average temperature values are corrected for precipitation, whereas the rate of evapotranspiration, the same soil and climatic conditions, the rate depends on soil moisture and thus, ultimately, of precipitation. As a result, in Turc's formula (1954) mean air temperature is corrected for precipitation to take into account different humidity conditions.

Formula proposed for temperature correction:

$$T_c = \frac{\sum P_i \cdot T_i}{\sum P_i}$$

where T_c - average annual temperature correction;

P_i - recorded monthly average precipitation;

T_i - recorded monthly average temperature.

The next step is assessing the value of annual average rainfall and average annual correct temperature, by applying the determined correlation. These values are used to calculate the effective precipitation, actually touching the ground. To calculate the parameter first actual evapotranspiration ER must be determined by using Turc's formula.

$$ER = \frac{P}{\sqrt{0{,}9 + \left(\frac{P^2}{L^2}\right)}}$$

where ER - actual evapotranspiration (mm/year);

P - mean annual total precipitation (mm/year);

L - the ability of the atmosphere evaporated.

$$L = 300 + 25 \cdot T_c + 0{,}05 \cdot T_c^2$$

Knowing the value of ER, effective precipitation Q is obtained simply:

Q = P - ER (mm/year)

To calculate the infiltration, SINTACS methodology proposes two ways to approach different to the case of an impermeable or low permeability soil and the permeable land. In the first case infiltration obtained by multiplying the appropriate value of effective precipitation infiltration coefficient χ, for the existing rock type:

I = Q · χ (mm/year)

If a highly permeable ground, use the total amount of P (without decreasing evapotranspiration), which is multiplied by an infiltration coefficient χ mainly based on texture:

I = P · χ (mm/year)

Using SINTACS method for evaluating infiltration for Motru EMC dumps, taking into account pluviometric data series for 21 years and stored material characteristics (in particular the share of different types of rocks), were obtained the data presented in table 6. It indicate that the rate of infiltration was counted a value of 0.4 because, although the landfill material is predominantly sandy clay, the high degree of mellowness (where fresh material is deposited) is a favorable condition for producing water infiltration from precipitation.

Table. 6 Effective rainfall infiltration dumps

	Year					
	2000	**2002**	**2003**	**2004**	**2005**	**2006**
P	333.40	798.10	780.50	1007.30	1121.90	871.90
Tc	12.04	15.10	10.99	13.32	12.66	12.76

L	688.27	849.56	640.99	751.26	717.88	722.76
ER	312.99	597.78	505.64	613.28	613.66	568.13
Q	20.41	200.32	274.86	394.02	508.24	303.77
I	8.16	80.13	109.94	157.61	203.30	121.51

3. Conclusions

On the hydrometeorological regime following findings are made:

- rainfall regime in the areas of Rosiuta quarry's waste dumps is relatively rich, with average annual amount between 746-906 mm, but there are years when they exceed 1180-1330 mm or decrease up to 430-580 mm;
- in 8 over the last 10 years they have exceeded average annual values of rainfall and temperatures. High values of annual average rainfall was recorded mainly in 2004 and 2005 (1007.3 respectively 1121.9 mm than the multiannual average of 726.3 mm - table no. 1), leading to an accumulation by infiltration of larger quantities of water in waste dumps body, being created so favorable premises for triggering landslides. It states that in 2004, in July and November were exceedances of the monthly average rainfall of over two times, and in July 2005 exceeded the monthly average of 3.9 times;
- maximum amounts of precipitation fell in 24 hours can sometimes exceed the average monthly by appreciable quantities. For statistical analysis shows that the area studied, at least every 10 years rainfall fell in 24 hours can reach 76-105 mm; every 20 years, the maximum quantities of rainfall fell in 24 hours can be between 87 - 124 mm; every 50 years between 102-160 mm, and once in 100 years they can total 115 -190 mm;
- having regard to the low permeability of the material stored in waste dumps belonging to EM Rosiuta, mostly heavy rain infiltration occurs with accumulation, and by depositing material over the water accumulated on the surface of steps leads to increased water pressure in the dumps body;
- potential infiltration was determined by hortonian mechanism, using for this purpose ILLUDAS and ASCE methods. ASCE method reveals that potential infiltration in the waste dumps occurs after a small curve, due to low permeability of the material stored and for the case of an 8-hour precipitation, infiltration potential decreases from 76 mm/h in the start to approx. 6 mm/h after an hour and a half, then maintaining this value. ILLUDAS method leads to higher values of infiltration potential, respectively 125 mm/h at the beginning of precipitation and 6.5 mm/h when it ends;
- relative infiltration determined by the same methods shows relative increase in the range of 8 h from 0 to 64.91 mm (ASCE) and from 0 to 111.25 mm (ILLUDAS). Infiltration phenomenon continues after rainfall stops, due to internal drainage that occurs as a result of a high degree of mellowness;
- effective infiltration was determined by the SINTACS, which revealed that the region where the waste dumps are located, evaporation capacity of the atmosphere is relatively high, meaning that a large proportion of water from precipitation evaporates (for the years studied, the specific effective precipitation, that part of rainfall that actually reaches the ground, is less than half of total precipitation). Thus, the average effective infiltration is very low in dry years (such as 2000) and can achieve part of the 5th annual average precipitation if very rainy years (2005 case).

On how water accumulates in the waste dumps the following comments are made:

- accumulation of water is based on precipitation infiltration and from springs;
- water infiltration is enhanced by rocks mellowness and rainfall intensity and duration;
- the phenomena of swelling clay rocks reduces the rate of infiltration, but in the same time gave in changing in the same degree of consistency and resistance characteristics of rocks;
- water disposal capacity by saturated rocks is low and, lack of seepage on slopes, even if the water level is high, indicates a low permeability of rocks and lack of possibilities for aquifer currents to occur.

Further research by some experiments in situ may contribute to a better understanding of how water is stored in the waste dumps and their hydrodynamic regime.

4. References

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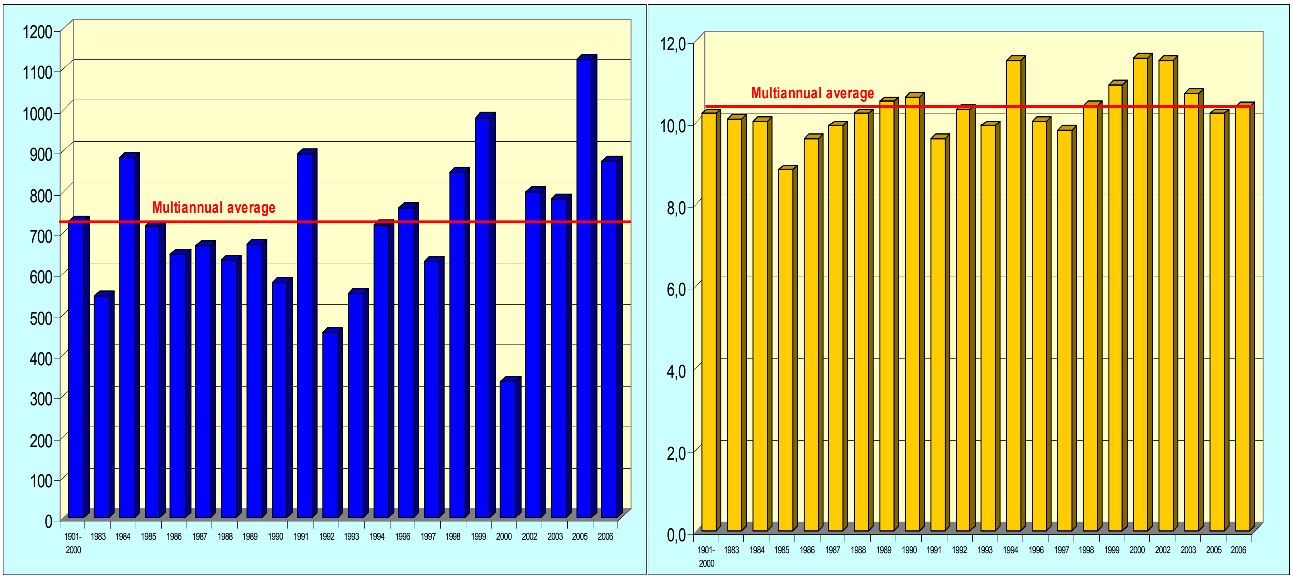

Fig. 1 Average annual rainfall and temperatures