

IMPACT OF REK BITOLA UPON PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL

Slobodan Bogoevski, Boško Boškovski, Gordana Ruseska

Faculty of Technology and Metallurgy, “Ss. Cyril and Methodius” University in Skopje, Ruđer Bosković, 16, MK-1000, Skopje, Republic of North Macedonia
s.bogoevski@tmf.ukim.edu.mk

A b s t r a c t: Contamination of soil by air sediment emitted from coal based thermal power plants is one of the basic ecological issue. The aim of this research is to define the impact of production of REK Bitola on the soils from defined microlocality in Pelagonia basin. Chemical, mineralogical and granulometric analyses were performed upon the soil samples. Also basic physical properties of the soil are determined. The chemical composition of the air sediment was also determined. According to the measured values and statistical data of REK Bitola, an average cumulative deposited quantity of air sediment is calculated, as well as the cumulative deposited quantity of trace elements in soil. The deposited air sediment has a negative impact on some of the basic physical and chemical properties of soil, but has no significant effect on the change in porosity and soil properties resulting from it.

Key words: REK Bitola; air sediment; soil properties

ВЛИЈАНИЕ НА РЕК БИТОЛА ВРЗ ФИЗИЧКИТЕ И ХЕМИСКИТЕ КАРАКТЕРИСТИКИ НА ПОЧВАТА

А п с т р а к т: Контаминацијата на почвите со аероседимент емитиран од термоелектричните центри на јаглен е основен еколошки предизвик. Целта на ова истражување е да се дефинира влијанието на долгогодишното функционирање на РЕК Битола врз почвата на дефиниран микролокалитет во Пелагониската Котлина. Направени се гранулометриска, хемиска и минералозна анализа на почвата и се определени и нејзините основни физички параметри. На аероседиментот му е определен хемискиот состав. Според измерените вредности и статистичките податоци за РЕК Битола е пресметана просечната кумулативна депонирана количина на аероседиментот, како и кумулативната депонирана количина на микроелементи во почвата. Депонираниот аероседимент има негативно влијание и ги нарушува основните физички и хемиски процеси во почвата.

Клучни зборови: РЕК Битола; аероседимент; почвени карактеристики

1. INTRODUCTION

REK Bitola produces approximately 70% of the electric power in the state [1, 2]. Thermal power plant was built near the coal deposits in Suvodol, Brod-Gneotino and Živojno. The location is 12 km eastern from Bitola (Figure 1).

Thermal power plant which burning coal has gas emission. This gas contain fly ash, and therefore is treated on electrostatic precipitator. The electrostatic precipitator in REK Bitola has efficiency of 99.84 %. Therefore 0.16 % of fly ash is emitted in the atmosphere as air sediment [1, 2].

REK Bitola has installed measured instrument, which implementing 24 hours continual monitoring. Also emitted air sediment is controlled on the 3 measurement points near the thermal power plant, in Ribarci, Gneotino and Debalci [3, 4].

The altitude of 580 m and surrounding mountain impose temperate-continental climate. Average annual rainfalls are 610 mm [5]. According to Wind Rose the direction of blowing is N (189‰), NE (63‰), E (22‰), SE (68‰), S (134‰), SW (41‰), W (61‰) and NW (83‰). The circulation of air masses provides distribution and deposition of the air sediment on wide area.

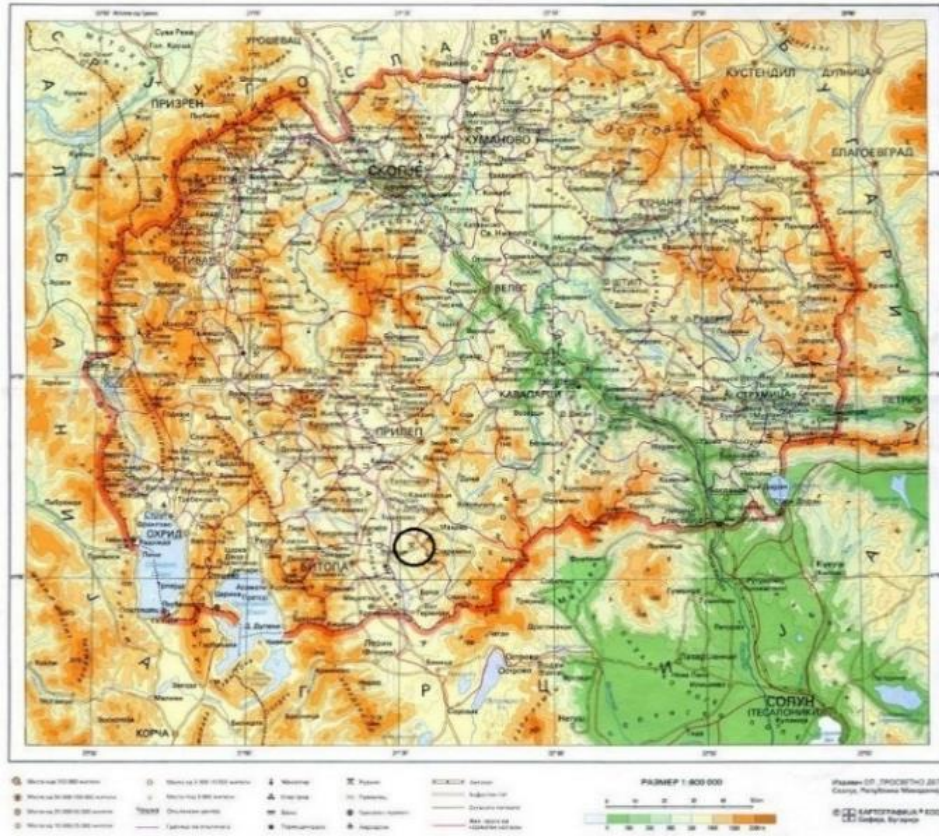


Fig. 1. Geographical map of the region

2. EXPERIMENTAL

In order to perceive the impact of REK Bitola on soils [6], is defined a microlocality around the thermal power plant with radius of 10 km (area of $3,14 \cdot 10^8 \text{ m}^2$), where the air sediment is deposited. There are defined 3 sample points I, II and III (Figure 2). From every sample point are collected cultivated (index 1) and uncultivated (index 2) soils for analysis.

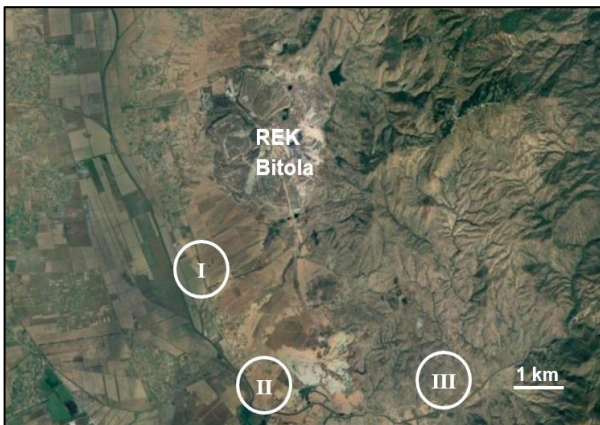


Fig. 2. Map of research area

Initially are determined the properties of the soils [7, 8]. In order to define granulometric composition of the soils [9], a wet sieve analysis has been realized. Chemical composition of the soil samples is determined by silicate chemical analysis. The existing minerals in soil have been identified by X-ray analysis, on Rigaku Ultima IV diffractometer [10–17]. pH value of soil samples is measured from 30% water suspension on pH meter Sartorius.

The quantity of the deposited air sediment is determined applying gravimetric method according to the equation:

$$X = \frac{m}{30 \cdot (r^2 \cdot \pi)} \text{-- (mg/m}^2 \text{ day)}, \quad (1)$$

where is:

X – average daily quantity of air sediment, ($\text{mg/m}^2 \text{ day}$);

30 – number of days in month;–

m – monthly quantity of air sediment (mg);

r – radius of circle pan where the air sediment is deposited (m).

Chemical composition of the deposited air sediment is also determined by silicate chemical analysis. Content of trace elements is determined by ICP-AES analysis on spectrophotometer Varian 715-ES.

3. RESULTS AND DISCUSSION

The mass contents of various dimensional fractions of grains are presented at Figure 3. From the histogram can be concluded that at all soil samples dominant with over 40% is fine fraction of grains (-0.032 mm). The other fractions have minimal contents, with exception of the dimensional fraction ($-0.25 + 0.1$ mm), which are in range of 12 to 20%.

Chemical composition of the soil samples is presented in Table 1.

Dominant mass content has SiO_2 with 67.86–69.13 %. The contents of Al_2O_3 are 11.74–12.37 %, and of Fe_2O_3 are 3.06–3.78 %. Soil contains of feldspars (XRD, Figure 4.), therefore in chemical

composition are determined Na_2O and K_2O . CaO and MgO are from the existing carbonate minerals in soils. Chemical analyses indicate that the soils from this area of Pelagonia basin have relatively homogeneous composition. Because the soil samples are collected from points with minimal distance (under 5 km) and have common pedogenesis, there is no significant variety. Consequently the material for X-ray examinations is collected as a composite sample from all soil sample points. From XRD (Figure 4) are determined minerals quartz, illite, K-feldspar, Na-feldspar and calcite.

In the coarse fractions of grains dominant are quartz and feldspars (Figure 5).

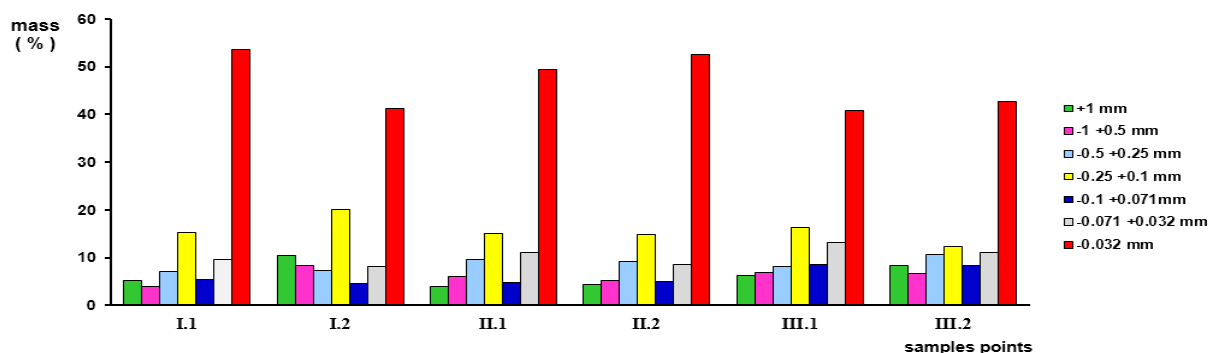


Fig. 3. Histogram of granulometric sieve analysis of the soils samples (mass %)

Table 1

Chemical composition of the soils samples (mass %)

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	l.w	Σ
I.1	68.27	12.24	3.06	3.45	1.00	2.51	3.13	0.13	6.12	99.91
I.2	69.12	12.37	3.15	3.00	1.29	2.19	3.04	0.10	4.95	99.21
II.1	67.86	11.87	3.78	3.57	1.14	2.29	2.85	0.15	6.34	99.85
II.2	69.12	11.74	3.49	3.45	1.04	2.19	2.57	0.11	5.79	99.50
III.1	68.52	12.23	3.21	3.60	1.15	1.80	2.57	0.09	6.51	99.68
III.2	69.13	12.18	3.42	3.23	1.08	1.70	2.65	0.12	6.12	99.63

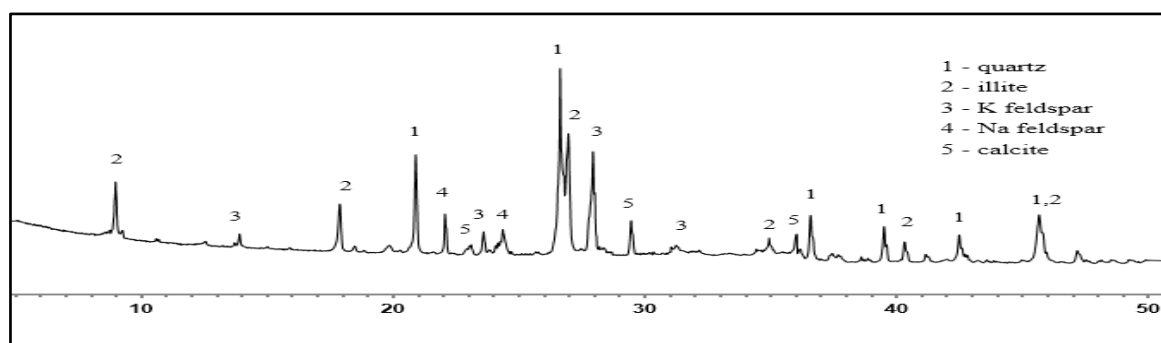


Fig. 4. XRD of the soil

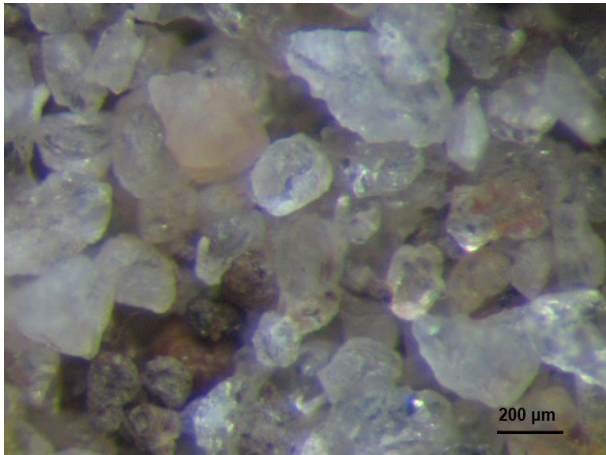


Fig. 5. Micrograph of dimensional fraction of grain ($-0.25 +0.1$ mm) from soil sample I.1

The pH value of soil samples are slightly acidic in the range from 6.4 to 6.7 (Table 2).

Table 3

Physical properties of the soil samples

	I.1	I.2	II.1	II.2	III.1	III.2
Specific density (g/cm^3)	2.6658	2.6503	2.5989	2.6429	2.5351	2.6065
Bulk density (g/cm^3)	1.5394	1.4281	1.5188	1.4994	1.4722	1.5181
Porosity (%)	42	46	41	40	45	41

Table 4

Chemical composition of the air sediment (mass %)

SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	SO ₃	P ₂ O ₅	TiO ₂	Na ₂ O	K ₂ O	Σ
59.75	9.57	17.89	4.68	2.10	3.45	0.09	0.71	0.69	1.01	99.94

Table 5

Contents of trace elements in air sediment (ppm)

Cd	Cr	Cu	Ni	Pb	Zn	Hg	As
3.2	74.16	72.32	81.52	14.28	109.6	0.2	0.4

Approximately taking in consideration the constant production parameters of REK Bitola (coal, capacity and other), average years quantity of emitted air sediment is calculated. Average yearly requirement of REK Bitola is 6 200 000 t of coal, which generate average 1 114 300 t of ash. Consequently the average quantity of emitted air sediment (0.16%) is 1782.88 t [1, 2]. Until today, during 38 years (1982–2020) REK Bitola cumulative has emitted 67 749.44 t of air sediment. In relation with

Table 2

pH values of soil samples

Sample	I.1	I.2	II.1	II.2	III.1	III.2
pH value	6.6	6.4	6.7	6.5	6.6	6.7

Also some physical properties of the soil samples are determined (Table 3).

The air sediment particle size varies in a wide range from 1 μm to over 10 μm [18]. Chemical composition of the air sediment is in correlation with chemical composition of burning coal in REK Bitola [19–21]. The coal has lower degree of wood carbonization. Dominantly contains fine fraction of coal fragments, then fragments of coal clay and coal tailings [22, 23]. Chemical composition of the air sediment is presented in Table 4. Contents of trace elements are presented in Table 5.

defined micro-locality of impact around the REK Bitola with radius of 10 km (area of $3,14 \cdot 10^8 \text{ m}^2$), calculated cumulative deposited quantity of air sediment on soil is 215.76 g/m^2 . In relation with defined bulk density of the soils, cumulative deposited quantities of air sediment in various soil horizons are calculated (Table 6).

Acidic reaction of deposited air sediment reducing the pH value of the soil. As a consequence of that the biochemical processes in soil are disordered. Distributed air sediment reducing the soil porosity, which cause negative impact on soil water permeability.

In relation with defined chemical composition of air sediment, cumulative deposited quantities of trace elements in soil are calculated. In Tables 7–9 are presented cumulative deposited quantities of trace elements in various soil horizons. The quantity

of the trace elements for all samples points is within the limited values [24]. With increasing of soil

horizon depth, the quantity of pollutants in soil is reducing [25, 26].

Table 6

Cumulative deposited quantities of air sediment in various soil horizons (g/kg)

Soil horizon depth (cm)	I.1	I.2	II.1	II.2	III.1	III.2
0 – 10	1.40159	1.51082	1.42060	1.43898	1.46556	1.42125
0 – 20	0.70079	0.75541	0.71030	0.71949	0.73278	0.71063
0 – 30	0.46715	0.50356	0.47348	0.47961	0.48847	0.47370
0 – 40	0.35040	0.37770	0.35515	0.35974	0.36639	0.35531
0 – 50	0.28032	0.30216	0.28412	0.28780	0.29311	0.28425
0 – 60	0.23360	0.25180	0.23677	0.23983	0.24426	0.23688
0 – 70	0.20023	0.21583	0.20294	0.20557	0.20937	0.20304
0 – 80	0.17520	0.18885	0.17757	0.17987	0.18320	0.17766
0 – 90	0.15573	0.16787	0.15784	0.15989	0.16284	0.15792
0 – 100	0.14016	0.15108	0.14206	0.14390	0.14656	0.14213

Table 7

Cumulative deposited quantities of trace elements (ppm) in soil horizon 0–10 cm

	I.1	I.2	II.1	II.2	III.1	III.2	Dutch standards list	
							Target	Intervention
Cd	0.00449	0.00483	0.00455	0.00460	0.00469	0.00455	0.8	12
Cr	0.10394	0.11204	0.10535	0.10671	0.10869	0.10540	100	380
Cu	0.10136	0.10926	0.10274	0.10407	0.10599	0.10278	36	190
Ni	0.11426	0.12316	0.11581	0.11731	0.11947	0.11586	35	210
Pb	0.02001	0.02157	0.02029	0.02055	0.02093	0.02030	85	530
Zn	0.15361	0.16559	0.15570	0.15771	0.16063	0.15577	140	720
Hg	0.00028	0.00030	0.00028	0.00029	0.00029	0.00028	0.30	10
As	0.00056	0.00060	0.00057	0.00058	0.00059	0.00057	29	55

Table 8

Cumulative deposited quantities of trace elements (ppm) in soil horizon 0–20 cm

	I.1	I.2	II.1	II.2	III.1	III.2	Dutch standards list	
							Target	Intervention
Cd	0.00224	0.00242	0.00227	0.00230	0.00234	0.00227	0.8	12
Cr	0.05197	0.05602	0.05268	0.05336	0.05434	0.05270	100	380
Cu	0.05068	0.05463	0.05137	0.05203	0.05299	0.05139	36	190
Ni	0.05713	0.06158	0.05790	0.05865	0.05974	0.05793	35	210
Pb	0.01001	0.01079	0.01014	0.01027	0.01046	0.01015	85	530
Zn	0.07681	0.08279	0.07785	0.07886	0.08031	0.07789	140	720
Hg	0.00014	0.00015	0.00014	0.00014	0.00015	0.00014	0.30	10
As	0.00028	0.00030	0.00028	0.00029	0.00029	0.00028	29	55

Table 9

Cumulative deposited quantities of trace elements (ppm) in soil horizon 0-30 cm

	I.1	I.2	II.1	II.2	III.1	III.2	Dutch standards list	
							Target	Intervention
Cd	0.00149	0.00161	0.00152	0.00153	0.00156	0.00152	0.8	12
Cr	0.03464	0.03734	0.03511	0.03557	0.03622	0.03513	100	380
Cu	0.03378	0.03642	0.03424	0.03469	0.03533	0.03426	36	190
Ni	0.03808	0.04105	0.03860	0.03910	0.03982	0.03862	35	210
Pb	0.00667	0.00719	0.00676	0.00685	0.00698	0.00676	85	530
Zn	0.05120	0.05519	0.05189	0.05257	0.05354	0.05192	140	720
Hg	0.00009	0.00010	0.00009	0.00010	0.00010	0.00009	0.30	10
As	0.00019	0.00020	0.00019	0.00019	0.00020	0.00019	29	55

4. CONCLUSION

REK Bitola's production has the impact on the soil. Taking in consideration the air circulation in the Pelagonia basin and the properties of air sediment, is defined a microlocality of impact with radius of 10 km around the thermal power plant.

From 3 sample points in defined area, are collected soil samples for analysis. On soil samples are determined granulometric composition, chemical composition, existing minerals, specific density, bulk density and porosity.

Also on air sediment is determined chemical composition. Taking in consideration the statistical data based on measured values of REK Bitola, calculated cumulative deposited quantity of air sediment in soil is 215.76 g/m². Also are calculated cumulative deposited quantity of the trace elements in various soil horizons, for all sample points. In surface soil horizon 0–10 cm the quantity of Cd was in the range from 0.00449 to 0.00483 ppm, Cr from 0.10394 to 0.11204 ppm, Cu 0.10136 to 0.10926 ppm, Ni 0.11426 to 0.12316 ppm, Pb from 0.02001 to 0.02157 ppm, Zn from 0.15361 to 0.16559 ppm, Hg from 0.00028 to 0.00030 ppm and As from 0.00056 to 0.00060 ppm. The content of pollutants is reducing with increasing of soil horizon depth.

Measured and calculated values of deposited quantity of air sediment in soils are compared with the values from Dutch National Standards for soil. The quantity of trace elements in soils are within the limited values, and is not a serious risk for human population. After finishing of defined producing period for REK Bitola (which is approximately 50 years), pollutants will going to be balanced in

soil without repercussions for the environment. Deposited air sediment is reducing the pH value and porosity of the soil. This has negative impact on water permeability and biochemical processes of the soil.

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