Cadmium content in soils and Oriental tobacco leaves: a study in tobacco-growing regions of southeast Bulgaria

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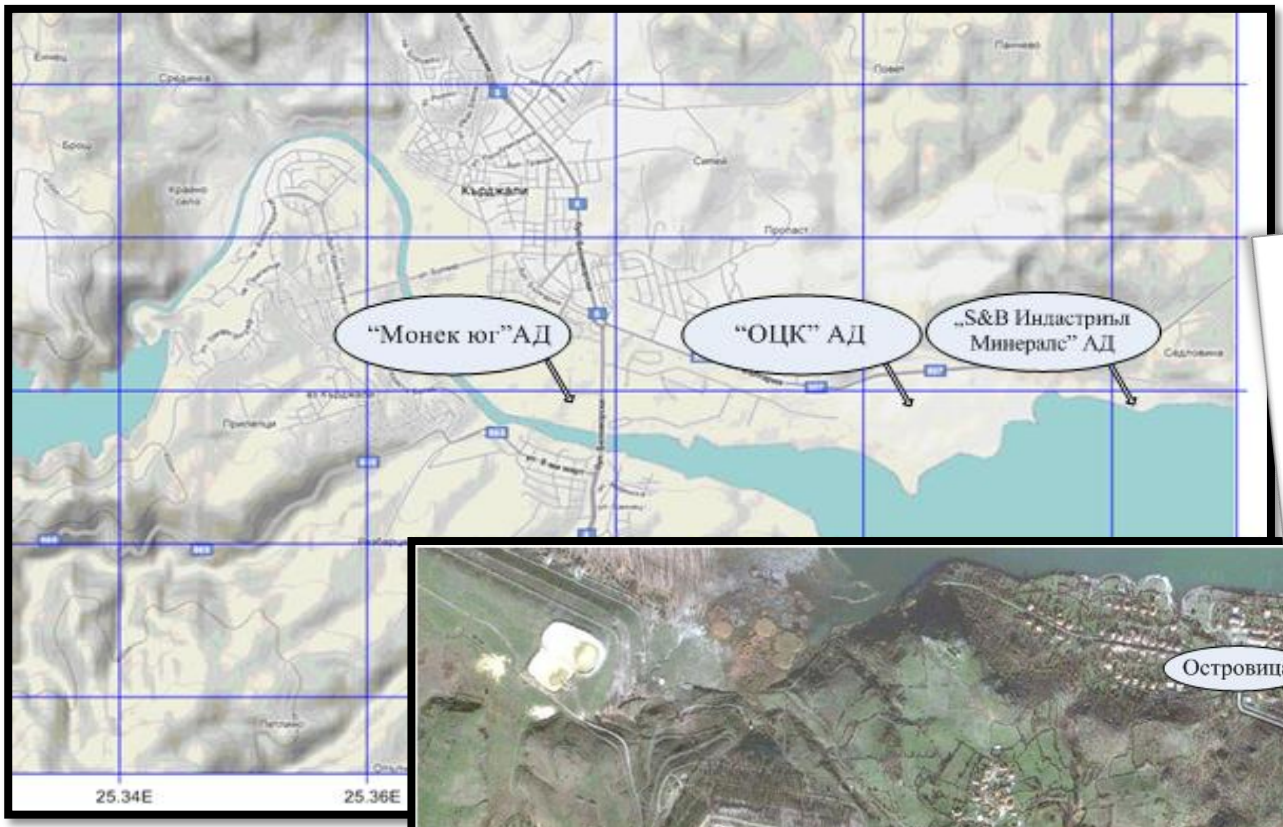
Aim:

- To identify possible contamination with Cd of soils and the Oriental tobacco grown on them.
- To ascertain the soil-plant relationships known to affect Cd take-up by plants.

Object of study: the Eastern and Central, and parts of the Western Rhodope Mountains in Bulgaria: tradition of Oriental tobacco growing (for centuries).

- Planting takes place in regions contaminated with heavy metals: Past industrial contamination with PM, SO_2, Pb+Cd aerosols.
- crucial to verify the safety of the produce.
- Offer possible alternative applications for tobacco plants.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Soils: eroded to varying degrees – mountainous and hilly terrain, deforestation, monoculture.

- Soil fertility and possible contamination of the crops are current issues.

- **Tobacco sector:** high demographic, economic and social importance, strategic to the economy still.
- Application in the pharmaceutical industry and as biofuel?

Materials and methods:

In 2016, 2017, and 2018, ***surface soil samples*** (0-30 cm) and ***Oriental tobacco leaves at technical maturity*** were collected ***at 38 sites*** in the municipalities of Kardzhali (Krumovgrad, Zlatograd, Ardino, Kirkovo) and Haskovo (Ivailovgrad, Harmanli).

Oriental tobacco samples were collected according to CORESTA Guide 13. The leaves were dried and homogenized. For plant analyses, a mean sample representing each sampling point was prepared.

Cd content was determined in accordance with ISO 14082 using ICP-AES.

The surface **soil samples** were collected in accordance with ISO 10381. Preparation for analyses was done according to ISO 11464.

The following indices were examined:

- **pH** in aqueous extract - ISO 10390
- **Humus content** - according to Tyurin
- **Soil texture** - according to Wigner
- **Total Cd content** by aqua regia digestion: ISO 12914 (microwave mineralization)
- Concentration of **mobile forms of Cd** - extraction with 0.005M DTPA + 0.1M TEA, pH 7.3, ISO 14870

Quality control

Three SRMs were employed:

- CRM045 (Silt Clay Soil) - total content of Cd in the soils
- NIMGBW07412A Soil (Brown soil) – mobile forms of Cd
- INGT-OBTL-5 (Oriental Basma Tobacco leaves) - for the plant analysis.

The measured values were found to be in very good agreement with the certified data.

Experimental

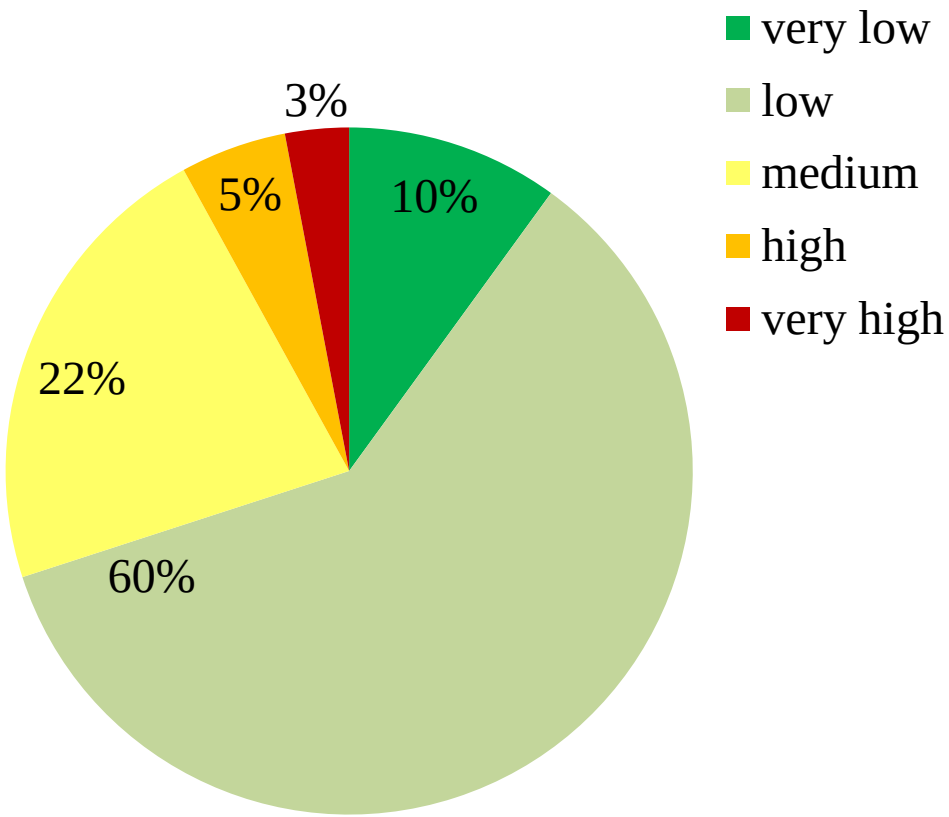
Table 1. Soil texture determined in the studied regions: soil fractions

Statistical index	Coarse sand (2 – 0.2 mm)	Sand (0.2 – 0.02 mm)	Silt (0.02-0.002 mm)	Clay <0,002 mm	Silt + clay <0,02 mm
Mean	23.49	39.94	13.54	23.03	36.58
Standard deviation	13.79	20.1	9.70	16.20	23.48
Range	56.68	77.73	33.73	56.66	73.40
Minimum	3.35	4.67	3.27	3.68	**8.54**
Maximum	60.03	82.40	37.00	60.34	**81.94**
CV, %	58.71	50.33	71.64	70.34	64.19

Predominant were soils with light texture and 27% of the soils were heavy.

Optimal for Oriental tobacco-growing: clay and silt faction content between 10% and 50% (i.e. sandy and clayey-sandy soils).

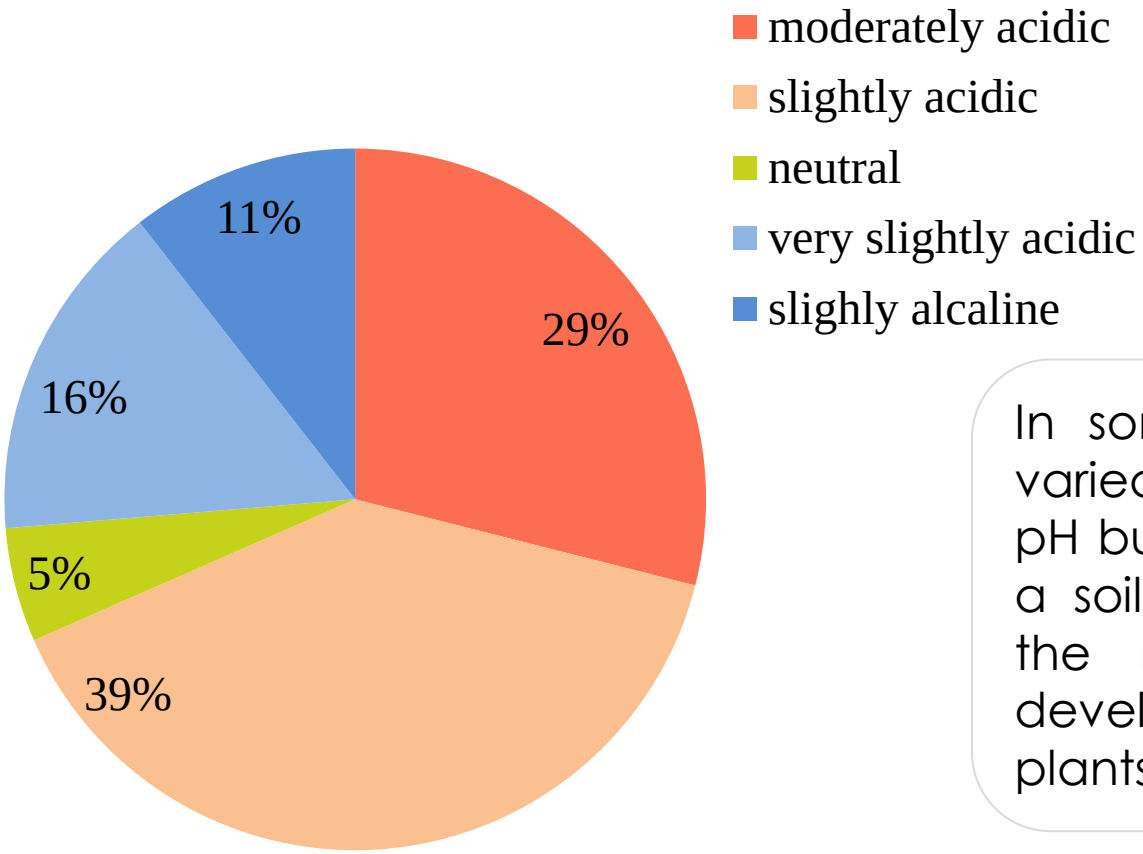
Distribution according to the humus content



The soil samples from the villages of: **Gluhar, Gradinka, Dryanova Glava, Opalchentsi, Panichkovo, Kondovo, Oreshino, Lyaskovo, Draganovo, and Konush** were characterized by the optimal for Oriental tobacco-growing sandy and clayey-sandy texture and low humus content.

Optimal for Oriental tobacco-growing: humus content between 0.8% and 2%.

Distribution according to the soil reaction (pH)



In some regions, the soils varied greatly in terms of pH but all the samples had a soil reaction suitable for the normal growth and development of tobacco plants.

Soil status: Ordinance #3 (2008) - For Cd content (pH, land use) - no instances of exceeding the IC and MPC.

Cd content determined in soil and plant samples

Table 2. Cd content (mg/kg): total content and mobile forms in soil, and Cd content in mature tobacco leaves (averaged data for 3 consecutive years)

	Cd m	Cd total	Cd tobacco
Mean	**0.17**	**0.58**	**2.17**
St. dev.	0.3	0.55	2.80
Variance	0.1	0.31	7.8
Range	1.46	3.15	15.50
Minimum	0.02	0.15	0.05
Maximum	**1.48**	**3.30**	**15.95**
CV, %	164	96	129

⇒ Cd was accumulated in the leaves of *Nicotiana tabacum* L., varietal group Basma, ecotype Krumovgrad

No visible signs of phytotoxicity

Soil status: Ordinance #3 (2008) - percentage of samples characterized by very low Cd content

(< precautionary level): 76%; (<background level): 45%


Municipal landfill!
Oriental tobacco!

Regression/correlation analyses

Variable X	Variable C – concentrations of the mobile forms of Cd in soil	R^2	*p*
Clay fraction	$C = 0.044 \cdot e^{0.031 \cdot X}$	0. 244**	0.002
Clay + silt	$C = 0.053 \cdot e^{0.015 \cdot X}$	0.244*	0.035
pH	no significant relationships	-	-
humus	$C = 0.050 \cdot 1.145^{X}$	0.275**	0.000
Cd total	$C = - 0.106 + 0.480 \cdot X$	0.908**	0.000
Variable X	**Variable C – averaged concentrations of Cd in tobacco leaves**	**R^2**	***p***
clay fraction	$C = 0.236 \cdot 0.584^{X}$	0.183**	0.007
silt + clay	no significant relationships	-	-
pH	$C = 68.9 \cdot e^{- 0.618 \cdot X}$	0.155*	0.015
humus	no significant relationships	-	-
Cd total	$C = - 0.389 + 4.444 \cdot X$	0.775**	0.000
Cd mobile	$C = 0.678 + 8.763 \cdot X$	0.764**	0.000

** Statistical significance at $p \leq 0.01$; * Statistical significance at $p \leq 0.05$.

Conclusions:

- **No instances of exceedance of the intervention concentrations and MPC** for Cd content were observed according to Ordinance #3 (2008).
- **The majority of the soil samples can be considered clean**: the determined total content of Cd was **lower than the precautionary and background concentrations.**
- The tobacco samples collected in crop fields located **at a distance of 10 m to 600 m to the municipal landfill** in Vishegrad were characterized by very high concentrations of Cd.
- **No symptoms of toxicity of the plants** were observed. Oriental tobacco exhibits **accumulating properties**, therefore planting in close proximity to known point sources of heavy metal contamination **should be prohibited**.

Conclusions:

- The performed correlation/regression analyses showed **significant positive linear relationships between the concentrations of Cd in the tobacco leaves and** both the total content and mobile forms of **Cd in the soils** ($p<0.001$).
- The exponential model described the relationship between the **soil pH and the Cd concentration in tobacco leaves**; as well as the relation between the **DTPA-extractable forms of Cd with the clay** (<0.002mm) **and the silt + clay** (<0.02mm) **fractions of the soil.**
- The power model adequately reflected the relation between the **mobile forms of Cd and the humus content**, and between the **clay content and the Cd concentration in the tobacco leaves**.


Thank you for
your attention!