

ERKKI JAUHIAINEN<sup>1</sup>**REGIONAL VARIATION OF SULPHUR AND TRACE METALS IN STONE PINE LANDSCAPE IN GREECE**

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The paper reports the results of analyses for sulphur, lead, cadmium and cobalt on needles collected from stone pines (20 sites) in Greece. The sulphur and lead concentrations are higher in Piraeus-Athens area than in the Greek rural area, probably reflecting similar regional differences in the atmospheric fallout. The mean sulphur and trace metal content gives the sequence  $S_{tot} > Pb > Co > Cd$ . The results suggest that stone pine needles are suitable for monitoring atmospheric pollution in the rural and urban landscape.

Variety is characteristic of the Greek geographical landscape. Vegetation and climate conform with the variations in the landscape. The trees are of medium height and vary from pine, oak and olive trees to fruit and palm trees. A result of the country's geographical location is also seen in its climatic range with mild winters and subtropically warm summers cooled by a system of seasonal breezes popularly called „meltemia“. An outstanding feature of the Greek climate is its ample sunshine. It is no exaggeration to state the sun shines in Greece for 3000 hours per year. The man's influence upon this Greek landscape element is seen very frequently. Smog hangs often over many industrial cities and landscape. Several recent studies in Finland have suggested that needles of conifers may be applicable to regional monitoring of air pollutants fallout, e. g. the investigations by Laamanen et al. (1969), Turunen et al. (1972), Laaksovirta et al. (1975), Pakarinen et al. (1976), Lehtiö (1981), Soikkeli (1981) and Jokinen et al. (1983).

The aim of this study was to determine the regional variation of sulphur and trace metals in 1 to 3-year-old needles of 30—50-year-old stone pines (*Pinus pinea*) collected from sites in eastern Peloponnese and Piraeus-Athens area in Greece. Attention was also paid to the proportion of air pollutants in the stone pines of the Greek landscape.

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MATERIAL AND METHODS

Needle samples were collected from twenty sites in March in the year 1981. The number of needle samples is presented from north to south (see Fig. 1) for sites 1—8. The sites 9—20 are from Piraeus to northeastern part of Athens. The collection sites are named 1. Delphi, 2. Ossios Loukas monastery, 3. Ko-

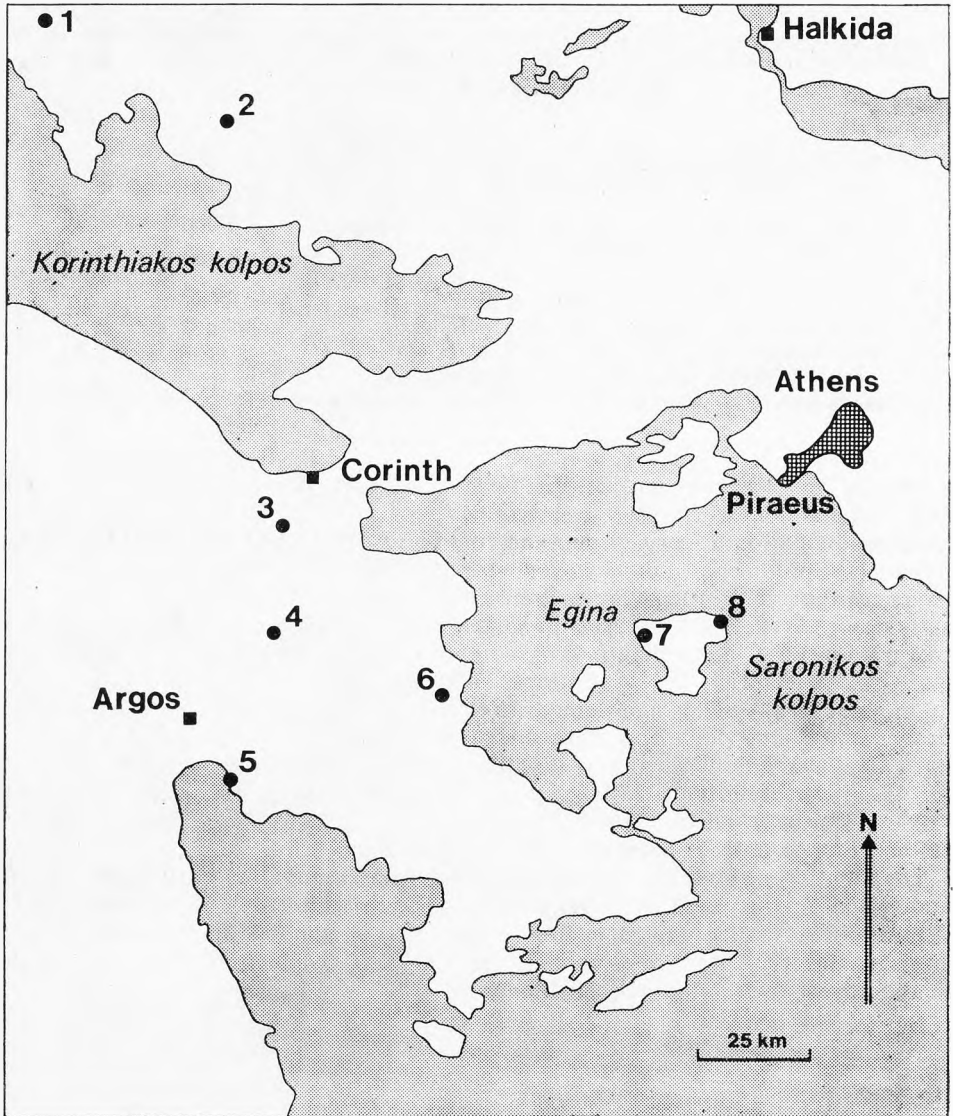


Fig. 1. Location of the study sites in Greece. Sites 1—8 are in the rural area and sites 9—20 in Piraeus—Athens area.

rinthos, 4. Mycenae, 5. Nauplia, 6. Epidaurus, 7. Aegina, 8. Aphaia, 9. Piraeus, 10. Petralona, 11. Pnyx, 12. Acropolis, 13. Athens Stadium, 14. Agii Asomati, 15. Pl. Eleftherias, 16. Akadimias, 17. Kolonaki, 18. Lycabettus, 19. Iraklio and 20. Kifissia.

The needles were sampled from different sides of each tree at a height of about 2—3 m and stored in plastic bags. Each sample was dried and homogenized. Sulphur, lead, cadmium and cobalt were determined by standard methods at Viljavuuspalvelu Oy in Helsinki.

## RESULTS

The total sulphur content of the needles seems to vary noticeably. The average sulphur concentration in the Greek rural districts material of the needles (0.95 mg/g) is about half as much as the mean for Piraeus-Athens collections (1.99 mg/g). The sulphur concentrations vary considerably between samples in the rural districts (Fig. 2). The maximum value of sulphur (1.8 mg/g) was found in site 5, which is located ca. 3 km from the small town Nauplia. The minimum value of sulphur (0.2 mg/g) was in site, 4, which is an open place near Mycenae. The regional patterns of the sulphur concentrations in Piraeus-Athens area are shown in more detail in Fig. 3. The sulphur content varied between 0.5 and 4.3 mg/g. High values were found in Piraeus (maximum of 4.3 mg/g in site 9) and in the center of Athens. Low concentrations were found in Acropolis and in the northeastern part of Athens.

The mean lead content of the stone pine needles is almost 5 times higher in Piraeus-Athens area than in the Greek rural districts (Table 1). In Piraeus-Athens area the lead content varied between 5.9 and 40.0 mg/kg. The maximum value of Pb was found in site 13, which lies near the Athens Stadium and the minimum value in site 19 in the northeastern part of Athens. The variation of the lead content is considerable. The maximum value of Pb in the Greek rural districts was found in site 5 (11.8 mg/kg), which lies near the small town Nauplia. The variation of the lead content is small and the minimum value was in sites 2, 3, 4 and 6.

The values of the cadmium content are in this material small. They varied between 0.030 and 0.063 mg/kg in the rural area and between 0.018 and 0.100 mg/kg in the urban area (Figs. 2—3).

The distribution pattern of cobalt is complicated (Figs. 2—3). The mean cobalt concentration of the stone pine needles is higher in Piraeus-Athens area than in the rural area. The inner variation in both groups is considerable. Low concentrations were commonly found in the rural area, but there is the small difference between rural and urban samples.

## DISCUSSION

The results are compared with some literature data. In general, the observed sulphur and trace metal concentrations are similar to or somewhat higher than the results of the few earlier analyses for needles (e. g. Pakarinen et al. 1976, Takala et al. 1981, Jokinen et al. 1983). The sulphur and lead concentrations are higher in Piraeus-Athens area than in the Greek rural area. This

difference may reflect the majority of the population and the industrial activity. Piraeus-Athens area lies in the valley and the flow of air is small. Some of the measured trace element content in needles probably represents surface contamination by dust. The mean sulphur and trace metal content gives the

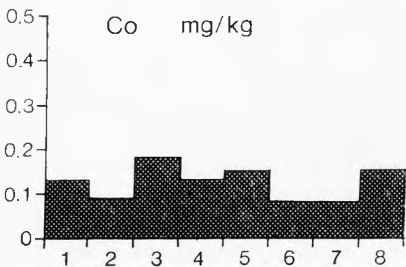
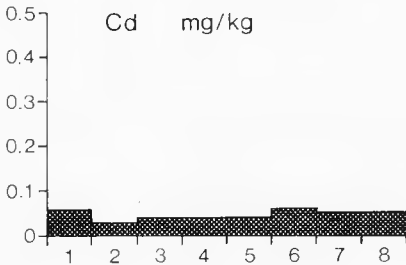
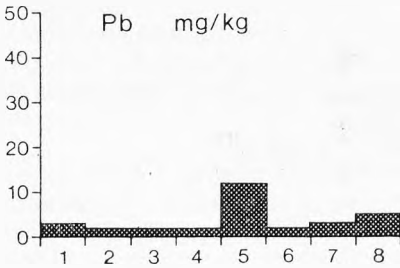
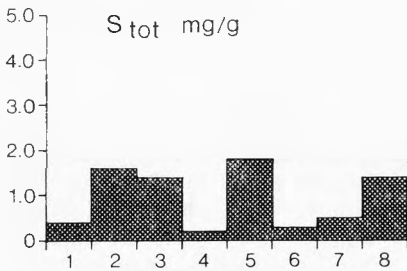


Fig. 2. Sulphur, lead, cadmium and cobalt concentrations in the Greek rural material.

sequence  $S_{tot} > Pb > Co > Cd$  in the present material. The study shows that the sulphur and trace metal content of stone pine needles can be used to assess the extent of air pollution in the rural and urban landscape.

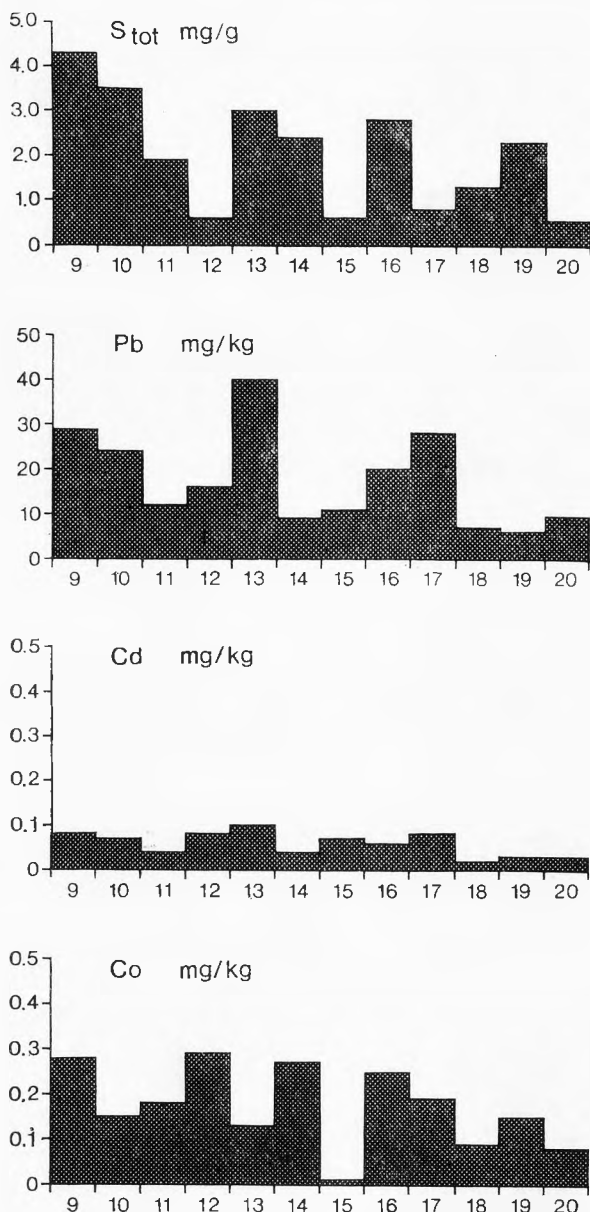


Fig. 3. Sulphur, lead, cadmium and cobalt concentrations in Piraeus-Athens area. See text.

Table 1. The mean sulphur and trace metal content in needles of stone pine in Greece. Mean  $\pm$  S. D., n.

S <sub>tot</sub>	Pb	Cd	Co
0.95 $\pm$ 0.81 (n = 8)	3.64 $\pm$ 1.86 (n = 8)	0.05 $\pm$ 0.01 (n = 8)	0.12 $\pm$ 0.04 (n = 8)
2.00 $\pm$ 1.27 (n = 12)	17.60 $\pm$ 10.64 (n = 12)	0.06 $\pm$ 0.03 (n = 12)	0.17 $\pm$ 0.09 (n = 12)

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#### REGIONÁLNE PREMENY SULFURU A STOPOVÝCH PRVKOV V KRAJINE S BOROVIČOU ALEBSKOU V GRÉCKU

Článok predkladá výsledky analýz síry, olova, kadmia a kobaltu v ihliciach nazbieraných z borovice alebskej (20 stanovišť) v Grécku. Koncentrácie síry a olova sú vyššie v oblasti Atény—Piraeus ako vo vidieckych gréckych oblastiach. Odzrkadľuje to pravdepodobne regionálne rozdiely v atmosferickom odpade. Priemerný obsah síry a stopových prvkov dáva sekvencie S<sub>tot</sub> > Pb > Co > Cd. Podľa výsledkov možno usudzovať, že ihlice borovice alebskej sú vhodné na monitorovanie atmosferického znečistenia vo vidieckej a mestskej krajine.

Obr. 1. Lokalizácia skúmaných stanovišť v Grécku. Stanovištia 1—8 sú vo vidieckej oblasti, stanovištia 9—20 sú v oblasti Atény—Piraeus.

Obr. 2. Koncentrácia síry, olova, kadmia a kobaltu v gréckom rurálnom materiáli.

Obr. 3. Koncentrácia síry, olova, kadmia a kobaltu v oblasti Atény—Piraeus (pozri text).

Tab. 1. Stredný obsah síry a stopových prvkov v ihliciach borovice alebskej v Grécku. Priemer  $\pm$  S. D., n.

РЕГИОНАЛЬНЫЕ РАЗЛИЧИЯ В НАЛИЧИИ СЕРЫ И ВКРАПЛЕННЫХ ЭЛЕМЕНТОВ  
В ЛАНДШАФТЕ С СОСНОЙ АЛЕПСКОЙ В ГРЕЦИИ

В статье докладываются результаты анализов серы, свинца, кадмия и кобальта в хвое, собранной с 20 мест произрастаний сосны алепской (*Pinus halepensis*) в Греции. Концентрация серы и свинца является повышенной в районе Афины — Пирей по сравнению с сельскими районами Греции. Это отражает, по всей вероятности, региональные различия в выпадении отходов из атмосферы. Среднее содержание серы и вкрапленных элементов дает секвенция:  $S_{tot} > Pb > Co > Cd$ . По полученным результатам можно сделать вывод, что хвоя сосны алепской подходит для мониторинга загрязнения атмосферы в сельской и городской местности.

Рис. 1. Размещение изучаемых мест произрастания сосны алепской в Греции. Места 1 — 8 находятся в сельской местности, места 9 — 20 расположены в районе Афины — Пирей.

Рис. 2. Концентрация серы, свинца, кадмия и кобальта в сельской местности в Греции.

Рис. 3. Концентрация серы, свинца, кадмия и кобальта в районе Афины — Пирей. Подробнее см. в тексте.

Табл. 1. Среднее содержание серы и вкрапленных элементов в хвое сосны алепской в Греции.  
Среднее  $\pm$  S. D., п.

Перевод: Л. Правдова