Preslia, Praha, 55 : 229—233, 1983

Indication of pollution by oil hydrocarbons by changes in vegetation

Indikace znečištění ropnými uhlovodíky podle změn rostlinného krytu

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PYŠEK A. (1983): Indication of pollution by oil hydrocarbons by changes in vegetation. — Preslia, Praha, 55 : 229—233.

The vegetation of 52 localities in the Czech Socialist Republic was studied following pollution by oil hydrocarbons. Many changes in the vegetation were found to have occurred because of contamination. Based on these vegetational changes, techniques for detection of oil pollution have been developed and tested in cases of oil pollution accidents.

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INTRODUCTION

The number of localities where oil hydrocarbon fuel is handled is increasing continually and the amount of spillage which causes environmental pollution is likewise increasing.

The influence of hydrocarbons on vegetation was studied in areas affected by long-term oil spillage; in areas of sudden accidents involving tankers and containers; in experimental plots where plants were gradually contaminated by oil; and in the area of Hodonín oil fields.

Botanical techniques for detecting oil pollution have been worked out within the framework of the State Investigatory Programme carried out in the Building Geology, Praha. The aim of the study was to use changes of plant cover caused by oil hydrocarbon pollution to estimate the extent of contaminated areas in relation to underground water protection.

Fifty two localities were studied using identical working methods.

The present paper is based upon a lecture given to the Conference of the Synanthropic Section of the Czechoslovak Botanical Society in Prague, on 29th November, 1980.

METHODS OF INVESTIGATION

a) Lists of species were made from contaminated stands and closely related non-contaminated stands. The frequency of occurrence of species has been estimated using a 1—5 degree scale;

b) Stands on plots selected at random were studies in detail;

c) Plant communities were analysed by phytosociological relevés using Braun-Blanquet's seven-degree scale for semiquantitative estimation of species population cover (= dominance);

d) The relative frequency of community occurrence on both contaminated and non-contaminated plots was found by using the "unit-area' method (unit-area equals 10 m^2 which are covered by a certain community and is easily estimated in the field by summation);

e) The zonation of vegetation along and across the main direction of the pollutant's output from the centre of contamination was recorded;

f) Permanent plots were established and analysed annually to reveal the successional tendencies of vegetation changes in the contaminated areas;

g) A survey was made of growth abnormalities exhibited by the species growing in the contaminated areas;

h) The course of phenological phases of the same species growing within and outside of the contaminated plots was compared;

i) All human activities prior to oil hydrocarbon pollution were documented.

RESULTS

The investigations, using the above-mentioned methods, of 52 contaminated localities in the Czech Socialist Republic (ČSR) yielded the following results:

a) Species which can be regarded as "petroleophilous" or "petroleotolerant" are: *Calamagrostis epigeios*, *Agropyron repens*, *Urtica dioica*, *Cirsium arvense*, *Sinapis arvensis*, *Rubus fruticosus* s. l., *Rubus caesius* s. l., *Sambucus nigra*, *Poa palustris* subsp. *xerotica*, *Epilobium angustifolium*, *Rumex obtusifolius* subsp. *obtusifolius*, *Dactylis glomerata*, *Agrostis stolonifera* subsp. *prorepens*, *Lotus tenuis*, *Carex hirta* and *Cardaria draba*;

b) species which can be regarded as "petroleocolous" or "petroleointolerant" are: *Pinus sylvestris*, *Poa pratensis*, *Chenopodium album*, *Arrhenatherum elatius*, *Betula pendula*, *Populus nigra*, *Festuca pratensis*, *Festuca rubra*, *Picea excelsa*, *Artemisia vulgaris*, *Conyza canadensis*, mosses and lichens;

c) "petroleophilous" plant communities are: *Calamagrostis epigeios*, *Agropyretum repentis*, communities with *Urtica dioica*, communities with *Rubus fruticosus* s. l. — *Rubus caesius* s. l., communities with *Rumex obtusifolius* subsp. *obtusifolius*, *Rumici-Agropyretum*, communities *Phragmites australis*, *Lepidietum drabae*, *Tanaceto-Artemisietum vulgaris tanacetosum*, *Melilotetum albae — officinalis*, communities *Lolio-Plantaginetum majoris* and *Polygonetum avicularis*;

d) the margins of the areas contaminated by oil hydrocarbons, "border zone", can be detected by a luxuriant growth of plants stimulated by a pollutant and by gradual increase in occurrence of "petroleocolous" species;

e) central and heavily polluted parts of the contaminated areas are later gradually invaded by vegetation by the following distinctive successional stages:

1. stages of therophytes and regenerating hemicryptophytes and geophytes;
2. stage characterized by the predominance of *Cirsium arvense*;
3. stage of communities from the alliance *Aegopodion podagrariae* or alliance *Convolvulo-Agropyrion*;
4. stage with *Sambucus nigra* as the predominating species or communities belonging to the alliance *Arrhenatherion elatioris*;

f) vigorous, almost gigantic growth of the following species has been observed in the contaminated areas: *Urtica dioica*, *Sinapis arvensis*, *Verbascum lychnitis*, *Viola arvensis*, *Cirsium arvense*, *Rumex obtusifolius* subsp. *obtusifolius* and *Campanula patula*;

g) quicker start (7 to 10 days less when compared with the normal habitats) of the flowering period in the populations of the following species has been recorded in the contaminated areas: *Barbarea vulgaris*, *Tanacetum vulgare*, *Cardaria draba* and *Sinapis arvensis*;

h) persisting light yellow pigmentation of the leaves of *Mahonia aquifolium* caused by presence of oil hydrocarbons has been found;

i) information on previous human activities in the contaminated area is necessary for successful indication of oil pollution.

TECHNIQUES OF STANDARD INDICATION

Summing up all experiences gained from the study of vegetational changes we can formulate the standard methods of detection of oil hydrocarbon pollution in the area of the Czech Socialist Republic.

The main procedures are:

a) to gather information on all human activities in the area under question;

b) to evaluate the occurrence and vitality of the "petroleophilous" species;

c) to observe the reaction of "petroleocolous" species;

d) to record all growth abnormalities performed by species present in contaminated area;

e) to observe the shift of flowering phenophases;

f) to try to detect the existence of the border zone of vigorous growth of plants.

DISCUSSION

When comparing the results of investigation of the influence of oil hydrcarbons on vegetation in the ČSR with the analogous data from the literature some interesting similarities have been found.

Decrease of total cover of stands and differentiated response of individual species to oil hydrocarbon pollution has been reported by BURK (1977) from Arcadia Wildlife Sanctuary, Massachusetts, USA. This corresponds to our results — the retreat of "petroleocolous" species and unchanged or increased dominance of "petroleophilous" plants were observed. Burk conseqently reported a strong negative impact of pollution on therophytes. The only "petroleophilous" therophyte, found growing on the contaminated places in the territory of the ČSR is *Sinapis arvensis*, whose response to oil pollution was represented by vigorous, almost gigantic growth. Commonly distributed therophytic species (e.g. *Chenopodium album* and *Conyza canadensis*) behave, however, like "petroleocolous" plants in our territory.

HUTCHINSON et FRIEDMAN (1975) studied the penetration of oil hydrocarbons into the active zones in soil in relation to the changes of vegetational cover in Alaska, USA. They found the complete disappearance of mosses and hemerophobic lichens and a differentiated response of individual phanerogams. On wet soils the vegetational cover is less affected than on dry soils, and the influence of oil pollution during the vegetational season is more pronounced than during the winter season. The authors described injuries observed on woody plants: *Picea mariana*, *Betula glandulosa*, and *B. nana*. A number of species reacted to the pollution by forming strong sprouts and gigantic leaves. Colonization of contaminated sites was much more effective than revegetation from the store of diaspores in the soil. The authors' conclusions correspond to the results obtained in the territory of the ČSR. Mosses and lichens seem to be less resistant and die off shortly after pollution (e.g. there was not a single living individual of a moss and a lichen in the plant communities of the alliance *Dicrano-Pinion*). Local trees, *Picea excelsa* and *Betula pendula*, are strongly "petroleocolous".

The finding by HUTCHINSON et FRIEDMAN (op. c.) of the tendency to larger growth among some species corresponds fully with our own results. The advantage for colonization of contaminated places by plants from its surroundings is documented in our case by the second successional stage with the prevailing anemochorous species *Cirsium arvense*.

Studies concerning the rules of regeneration of the vegetational cover after oil contamination, where carried out by HUTCHINSON et HELLEBUST (1978) and HUTCHINSON et FRIEDMAN (1978) in the Canadian Arctic at Norman Wells and in North Alberta. Vegetational cover was experimentally contaminated partly by spraying and partly by pouring oil on experimental sites. The response of vegetation in 100 m^2 plots was studies using various methods. The following were considered to be the decisive factors of natural regeneration: successful ecesis of seedlings; spreading of diaspores; and vegetative reproduction from tubers and rhizomes. The authors cited above also described a so called "border effect" performed by plants which gigantic leaves. The impact of pollution was found to be more devastating in tajga than in tundra habitat.

HUTCHINSON et HELLEBUST (op.c.) also found that the grasses *Calamagrostis purpurascens* and *C. canadensis* were growing successfully on contaminated sites and their dominance increased. Species of the genus *Calamagrostis* were recommended by the authors to be used for recolonization of polluted areas.

The border effect, as described by HUTCHINSON et HELLEBUST, corresponds to our border zone which denotes the periphery of the polluted area and is particularly important for a standard indication. Of our *Calamagrostis* species, *C. epigeios* belongs to the group of "petroleophilous" species growing successfully in contaminated areas and quickly increasing its dominance (PYŠEK et ŠVOMA 1978).

The synthetic work by COSTERTON et al. (1978) summarizes and evaluates all studies published in Canada.

GUDIN (1973), in his investigation of changes of plants caused by oil pollution, found that the prolongation of internodes and the enlargement of the size of plant bodies was characteristic.

In the ČSR, Z. Hartman of Brno is also engaged in problems concerning the influence of oil pollution on vegetation (HARTMAN 1977). His results correspond to the results presented in this study.

SUMMARY

Changes of the vegetational cover caused by the influence of oil hydrocarbons are described. "Petroleophilous" species not inhibited in their growth by contamination are listed as well as "petroleocolous" species, which are eliminated from the polluted stands.

Contaminated areas are covered by some twelve plant communities. The existence of a "border zone" formed by vital "petroleophilous" species is described. This zone denotes the peripheral limits of the extent of pollution within the contaminated stands.

Spontaneous revegetation of contaminated areas is differentiated into the individual successional stages.

The list of species which respond to oil pollution by abnormal growth or by a quicker (7 to 10 days) start of the flowering period is provided.

In all contaminated areas the general resulting phenomena are: the decrease of dominance of the whole stand; decrease of species diversity; and ruderalization of plant communities. Results obtained from the territory of the Czech Socialist Republic are compared with results from abroad.

SOUHRN

V rámci práce jsou popsány změny, ke kterým dochází ve vegetačním krytu vlivem ropných uhlovodíků. Jsou uvedeny druhy, kterým kontaminace ropnými látkami nebrání ve vegetování nebo je dokonce podporuje (petroleofily) a druhy, které jsou znečištěním vylučovány (petroleofóby). Kontaminové plochy porůstají zpravidla některá ze jmenovaných petroleofilních společenstev. Je popisována existence okrajového pásu z velmi vitálních petroleofilních druhů, která prozrazuje plošný rozsah kontaminace. Spontánní zarůstání zasažených ploch je diferencováno v jednotlivá sukcesní stadia. Je uveden soupis druhů, které reagují na ropné znečištění abnormálním vzrůstem, ev. zrychlením nástupu fenofáze kvetení o 7—10 dní. Na kontaminovaných lokalitách je obecným průvodním jevem snížení pokryvnosti porostů, snížení druhové diverzity a ruderalizace porostů. Výsledky získané v ČSR jsou srovnávány s výsledky prací zahraničních autorů.

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Received 13 April 1981

E. Hadač:

Krajina a lidé

Academia Praha 1982, 156 str., 15 obr., 40 foto na křid. přílohách, cena 35 Kčs. (Kniha je v knihovně ČSBS.)

Recenzovaná kniha je podle celkového zaměření i podle určení autora úvodem do krajinné ekologie, obracejícím se spíše k širší veřejnosti nežli ke specializovaným odborníkům. Její extenzívní pojetí vyplývá též z velkého záběru, ve kterém je zahrnuto nejen celé území ČSSR, ale i celý povrch Země. Dílo je rozděleno na pět hlavních částí a opatřeno stručným výtahem v angličtině a slovníčkem důležitých termínů z oboru krajinné ekologie.

V úvodní části (str. 9—27) je stručně nastíněn vývoj vztahů mezi krajinou a člověkem a vznik tzv. technoantropocenóz. Dále jsou vysvětleny hlavní pojmy: „základní krajinný celek", „kraj. složka", „kraj. typ", „skupina kraj. typů", „série kraj. typů" aj. Druhou část (str. 28—63) tvoří charakteristiky sérií krajinných typů různých klimatických pásem Země, od pólů až po rovník. Jednotlivé charakteristiky obsahují: základní krajinné složky, klimatické podmínky (ilustrované pomocí klimadiagramů), odhad celkové rozlohy na Zemi, charakteristické půdní typy, údaje