Acid rain: rehabilitation of the air-pollution-damaged headwaters of the Jizera mountains

Dr. Josef Krecek, Czech Technical University, Prague, Czech Republic

Background

Acid rain causes problems in both aquatic and terrestrial ecosystems. Increased soil acidity results in die-off of acidophobic plants and soil-dwelling organisms, and changes in soil chemistry, such as nitrogen saturation and decreased nutrient levels, further impact the flora and fauna. Soil microbes, unable to tolerate even small pH changes, are among the most affected and their die-off impacts decomposition cycles. Lakes and rivers suffer dramatic decreases in levels of biodiversity, with fish being particularly susceptible, as reduced pH causes failure of fish eggs to hatch, and further reduction kills off adults. Acid pollution can also affect human health, decrease the quality of fresh water, and, by causing changes in the soil-vegetation complex, it affects levels of runoff in watersheds. Thus, services provided by headwater ecosystems deteriorate through the processes of acidification.

One of the main causes of acid rain is the burning of soft coal in power stations, which leads to acid atmospheric deposition – loading of acidic compounds in the atmosphere, mainly sulphates, nitrates, and ammonia. The epicenter of acid deposition in Europe is known as the "Black Triangle," a heavily industrialized region at the border between the Czech Republic, former East Germany, and Poland. In the center of the Black Triangle are the Jizera Mountains, an area of 350km^2 affected mainly by industrial emissions from Poland and Germany.

The Jizera Mountains region is an important source of freshwater, timber and recreation. Acid atmospheric deposition peaked in the region in the mid-1980s. At that time, mountain ecosystems suffered from extreme acidity of soil and water bodies. By 1989, over two thirds of the spruce plantations had been heavily damaged by acid rain. This left fragmented forests and extensive clearings dominating the mountain watersheds throughout the 1980s and 1990s. The commercial harvest of spruce stands (heavily mechanized – using tractors to pull the felled trees out of the forest) caused rises in direct runoff, soil erosion and sedimentation. However, the subsequent growth of grassland at clear-cut sites played an important role in the soil and water protection. In the 1990s, the first signs of recovery in stream and lake waters were observed. In the last two decades, strengthened laws, improved policies, and ecological and technological advances have led to a significant drop in sulphur emission levels, therefore reducing air pollution and acid atmospheric load, which has led to recovery of mountain waters, chemistry, and biota.

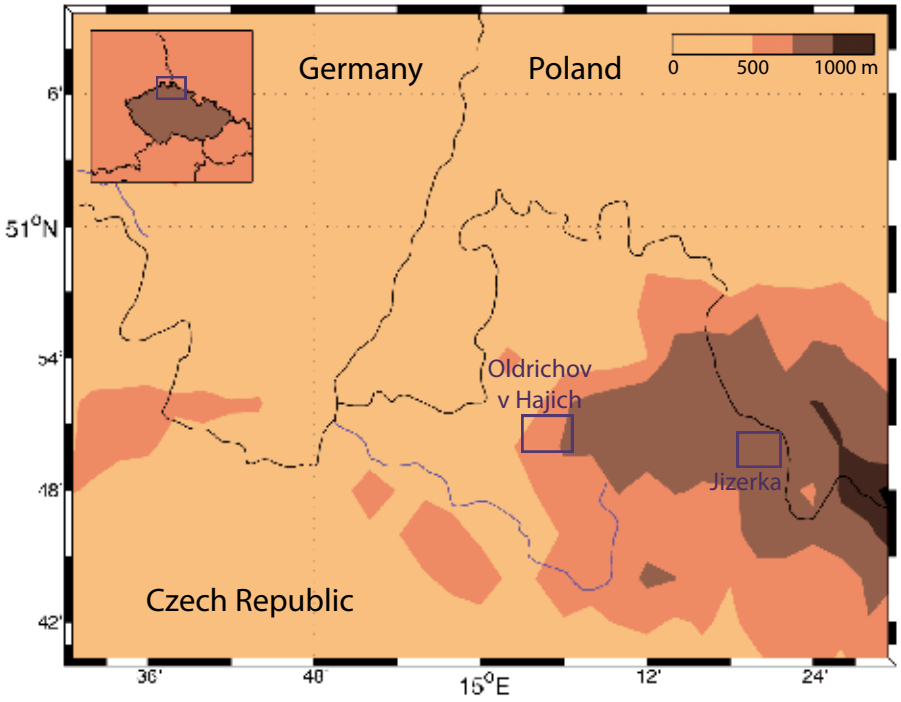

Figure 1. The locations within the Czech republic of the project's two experimental basins, at the villages of Jizerka, in the upper plains of the Jizera Mountains, and Oldrichov, in the western Jizera Mountains.

Project overview

The Earthwatch project, headed by Dr. Josef Krecek, focuses on the analysis, restoration and protection of headwater ecosystems in the Jizera Mountains, northwest Czech Republic. Dr. Krecek began conducting research in the area in 1980 and Earthwatch volunteers first joined the project in 1991, making 2010 the project's 20th field season with Earthwatch. This case study looks at the entire research period to date, highlighting key outcomes over the years, and demonstrating the legacy that has been left by the Earthwatch scientists and volunteers.

The goal of this long-term research is to evaluate trends in decline and recovery related to levels of pollution, specifically acid deposition, and to investigate alternative practices for watershed and lake management. The study is identifying optimal strategies for rehabilitation of

Volunteers checking one of the monitoring stations which have been established throughout the experimental basins within the Jizera Moutains.

headwater catchments and lakes, by verifying the environmental effects of those strategies tested in several key watersheds within the Jizera Mountains. The multidisciplinary research – studying climate, hydrological cycle, atmospheric load, soil-vegetation complex, water quality, and other bio-geo-chemical processes – is carried out within specially established experimental basins. The data contributes to assessment of critical atmospheric loads and design of watershed management, as well as to the national action plan on sustainable management of mountain resources.

The following are the most recent project objectives:

- Conduct long-term monitoring of hydrological and bio-geo-chemical processes at fixed locations to provide baseline data
- Record the effects of forestry practices on the hydrology and biogeochemistry of watersheds
- Evaluate the hydrological effects of reforested catchment of Jizerka, harvested in the 1980s
- Evaluate the environmental benefits of different forest compositions – plantations of Norway spruce (*Picea abies*) or Colorado spruce (*Picea pungens*), the latter of which is more resistant to air pollution but not native, compared to stands of native composition which are mainly mixtures of common beech (*Fagus sylvatica*), common fir (*Abies alba*), and Norway spruce (*Picea abies*)
- Investigate episodic acidification of headwater streams and reservoirs
- Experimentation into liming of reservoirs to test a variety of strategies for increasing pH of the water
- Assess the role of semi-natural beech forests in the nature reserves of the Oldrichov basin
- Assess the self-sustainability of fish populations since acidification of waters
- Assess the environmental effects of herbaceous vegetation in mountain watersheds

Earthwatch volunteers collect data towards these objectives from more than 30 stream and three reservoir sites in the research area.

Outcomes and actions

Throughout the project, two experimental basins have been established by the scientists within which to test management strategies. The first basin was established in the early 1980s before the Earthwatch project began, near Jizerka, a hamlet in the upper plains of the Jizera Mountains. The area had been harvested by the commercial clear-cut of mature spruce plantation stands between 1984 and 1988, and Earthwatch volunteers became involved during the difficult, but eventually successful, reforestation effort between 1989 and 2000. Immediately after the clear-cut, the basin was reforested, but progress in forest regeneration was low, and invasive herbaceous vegetation dominated. This resulted in increased stream flow, accelerated loss of soil, low pH values, and high content of toxic metals (particularly aluminum), which caused declines in benthic fauna and extinction of fish in streams and reservoirs. It was therefore evident that forestry practices can significantly influence acidification levels in soils and waters. Through studying this experimental basin, Earthwatch scientists have documented a paradoxical relationship between decreased canopy area of spruce plantations and reduced levels of acid deposition. Effectively, the removal of spruce trees therefore results in improved water quality in streams and reservoirs (e.g. elevated pH and reduced sulphate and aluminum levels). Recent re-growth of forest stands, particularly coniferous species, is being monitored closely as it may result in a new period of increased acidity. Data are showing that under the spruce canopy, deposition of sulphur has increased in 2009 to 12–24kg per ha per year, meaning higher acid content in the soil and the resulting disturbance of soil processes.

In 1994, a second experimental basin in Oldrichov, containing semi-native beech stands, was fully established. Here, the forests have been controlled only by selective cutting to support regeneration of a native beech canopy, and again between 2005 and 2008 to aid recovery from mortalities related to extreme wind and snow conditions. As in Jizerka, detailed annual inventories of forest stands have been, and continue to be, carried out, including data on tree height, basal area, horizontal canopy area, vertical canopy distribution, leaf area index, vitality of trees, and evidence of herbaceous

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vegetation, to quantify the signs of catchment revitalization.

In 1995, the Earthwatch team began reintroduction of fish, specifically acid-tolerant brook char (*Salvelinus fontinalis*), to streams and reservoirs. Brook char is now the dominant species, the native brown trout (*Salmo trutta*) population which survived naturally has stabilized, and minnow (*Phoxinus phoxinus*) have re-established themselves in some watersheds. Work is being done to support this initial recovery and address an observed reduction in char numbers within the waters of the upper mountain plains. Results have shown that brown trout prefer less acidic waters and show seasonal congregations in different areas depending on pH level and levels of toxic aluminum in the water.

Recently, overall recovery of surface waters has been observed, attributed to decreased industrial emissions and the introduction of local liming strategies. However, this progress in recovery of biota following the drop in the atmospheric load has occurred after a relatively long delay period. For forest biota the scientists are using Ellenberg's indicators for geo-botanical characteristics – light, moisture, nitrogen, and acidity – and finding a delay of almost ten years. Composition of algal mats and fish populations in surface waters are responding to the environmental changes with an even longer reaction time. The recent status of restoration is still fragile, indicated for example by deformed gills in the reintroduced brook char, which signifies high levels of stress caused by toxic aluminum and heavy metals. Liming has had an adverse effect, causing significant changes in the biomass of phytoplankton and zooplankton. With the seasonal changes in hydrological processes that occur in autumn, unexpected peaks of zooplankton and phytoplankton have been observed, leading to problems with the drinking water. Studies on different approaches to liming are continuing to further investigate these findings.

In reaction to the findings of the Earthwatch research, management of the mountain watershed has moved away from focusing solely on a priority of timber production, to a more integrated approach which encompasses management for recovery of water resources as well. Scientists found that the semi-natural beech stands (which show higher ecological stability and acid resistance than spruce plantations) play an essential role in stabilizing soil, and conserving the forest microclimate and hydrological regime. Long-term project outcomes have included support provided towards protection of an existing nature reserve of common beech in the Jizera Mountains, which is the largest complex of beech forests in the Czech Republic. At the national level, the research has provided information on water resource control to the Watershed Authority of the Elbe River, which originates in the Krkonoše Mountains before flowing through northern Czech Republic and Germany to the North Sea. The European Working Group on the Management of Mountain Watersheds (part of which stems from the European Forestry Commission (EFC) and the Food and Agricultural Organisation (FAO) of the United Nations) has been using the findings of the research program in discussions on development of policies for watershed management across European mountain regions. Data have been used by the International Association on Headwater Control for preparation of the official *Guidelines on Revitalization in Headwater Catchments of Central Europe*, and have been incorporated into international scientific networks such as The International Cooperative Program on Assessment and Monitoring Effects of Air Pollution on Rivers and Lakes (a European Economic Community in the United Nations project) and on European Union mountain lake conservation programs.

Scientist profile

Dr. Josef Krecek is Associate Professor at Czech Technical University. He was chair of the EFC/FAO Working Group on the Management of Mountain Watersheds, and a Visiting Professor of Texas Woman's University, Denton, USA, in 1994 and the Research Institute for Humanity and Nature, Kyoto, Japan, 2005 to 2006.

Collaborative organizations

- The Watershed Authority of the Elbe River, Czech Republic
- The EFC/FAO Working Group on the Management of Mountain Watersheds in Europe
- International Association on Headwater Control

Project website

www.earthwatch.org/exped/krecek.html

Key publications

Krecek, J. & Novakova, J. (2009) Soil water content and plant succession after the harvest of mature spruce stands in a mountainous catchment. Ecology (*Bratislava*), **28:** 213-224.

Krecek, J., Horicka, Z. & Novakova, J. (2009) Environmental impacts of the acid atmospheric deposition and forest clear-cut in a mountain catchment. In: Fukushima, Y., Burnett, W.C., Taniguchi, M., Haigh, M. & Umezawa, Y. (Eds.) *From Headwaters to the Ocean*. Taylor & Francis Group, London.

Krecek, J., Novakova, J. & Horicka, Z. (*In press*) Ellenberg's indicator in water resources control: the Jizera Mountains, Czech Republic. Ecological Engineering, 1619.

Huge amounts of laboratory analysis are needed for vegetation, soil, and other samples collected in the field.