Monitoring of Atmospheric Deposition in South Tyrol

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INTRODUCTION

The aim of the program, started by the Biological Laboratory of the Environmental Agency of the Province of Bolzano-Bozen in 1983, is the monitoring of the chemical composition of the atmospheric precipitations, whose quality is influenced by human activities and natural forces. Analyses are performed in weekly samples collected both in the open field and within the forest in order to quantify the concentration of the acidic compounds, nutrients and base cations.

The study began as a research project of local interest and was later associated to national and European projects (Rete Italiana per il controllo delle deposizioni atmosferiche - RIDEP, ICP-IM, Con.eco.for, Futmon and other). The interest for the chemical composition of the atmospheric precipitation aroused because of the adverse effects exerted by atmospheric pollutants on the environment, particularly on forest, aquatic and terrestrial ecosystems. The monitoring allows more responsible decisions concerning the level of the air pollutants and provides the means for checking the effectiveness of the undertaken measures.

Air pollution exerts effects:

On the human population: Hundreds of substances present in the air are considered harmful. Many of them induce genetic mutations or cancer, respiratory problems and other disturbances. Many of these substances are organic compounds or metals like mercury, arsenic and cadmium. Emissions of sulphur (SO_2) and nitrogen dioxide (NO_2) can produce asthma, dry cough, headache and irritation of eyes, nose and throat.

On forest and soil: Sulphur and nitrogen acidic compounds, present in atmospheric precipitation, dissolve the nutrients of the soil and subtract from the trees vital elements like calcium and magnesium. Beyond a certain acidity level precipitation induce damages to the conifer's needles. Nitrogen oxides, also present in precipitation, act as fertilisers and force trees to grow often also in unfavourable periods.

On lakes and other aquatic ecosystems: The input of acids can produce sudden acidity increases in lake ecosystems (particularly during thaw in the spring). The reproduction of many amphibian, fish and insect species may result impaired. An indirect consequence of the acidic input to the aquatic ecosystem is the increased dissolution of toxic metals from rock and soil.

On materials and architectonic works: Air pollutants may damage art works such as paintings and sculptures and consume monuments, materials and architectonical works.

The monitoring of the atmospheric deposition chemistry of South Tyrol started in 1983 at four sites with bulk sampling. The first wet sampling station was set up in 1985. Since 1994 beside bulk and wet also throughfall, stemflow and soil water analysis are being performed at two forest monitoring sites (Ritten and Montiggl).

Fig. 1: The currently sampled sites are: **Ritten** 1780 m altitude and **Montiggl** 530 m

WHAT DO WE MEASURE?

- Acidity: determined by the hydrogen ion concentration. Atmospheric precipitation is slightly acidic also in an unpolluted atmosphere, but pollution can increase acidity to levels particularly dangerous for aquatic organisms.
- Sulphate: partly generated by natural sources (such as volcanic and other geothermal activity) have greatly increased because of the burning of fossil fuels.
- Nitrate: also partly generated by natural sources (biomass burning, microorganisms, lightening), they increase because of automobile exhaust and industrial emissions. Atmospheric deposition of nitrogen can have a fertilising effect on ecosystems.
- Ammonia: has a neutralising effect on precipitation, but once deposited can be converted to nitrate and contribute to soil and water acidification.
- Base cations: contained in dust from soils, unpaved roads, industrial emissions and salt spray from the oceans. When contained in alkaline minerals they can neutralize the acids in precipitation (transport of Sahara dust); when contained in neutral salts they generally have no effect.
- Dissolved carbon: to determine the input and loss fluxes of carbon to and from the forest
- Trace metals

HOW DO WE MEASURE?

Open field
We measure concentrations in "bulk" samples (collectors are always open) and in "wet-only" samples taken by devices which automatically collect the precipitation sample only during rainfall and store it afterwards closed.

Sampling in the forest experimental sites:

- Throughfall: samples are taken weekly from 16 samplers regularly distributed within the experimental site
- Stemflow: weekly samples are taken from 3 special samplers
- Soil solution: samples are taken weekly from 5 pan lysimeters
- Runoff: weekly sampling

SITUATION

The level of the pollutants concentration in atmospheric precipitation and their deposition values, recorded both in the open field and within the forest, are in South Tyrol lower than in the neighbouring areas because of the low amount of precipitation typical for the area and also because of the lower concentration of industrial plants. The northern edge of the Alpine chain partly blocks the long-distance transport of pollutants, limiting the pollution coming from north and east while even remote sites can be influenced by pollutants coming from the south. The relatively high inorganic nitrogen values are probably due to the high level of vehicular traffic along one of the main communication lanes between north and south (nitrates) and to agricultural activities and livestock production (ammonium emissions).

ACIDITY

The pH of pure water in equilibrium with the carbon dioxide present in the air has a value of 5.6. Higher pH values, indicate the presence of dissolved basic elements like calcium, magnesium, potassium and ammonium, while lower values indicate the presence of sulphuric, nitric or organic acids.

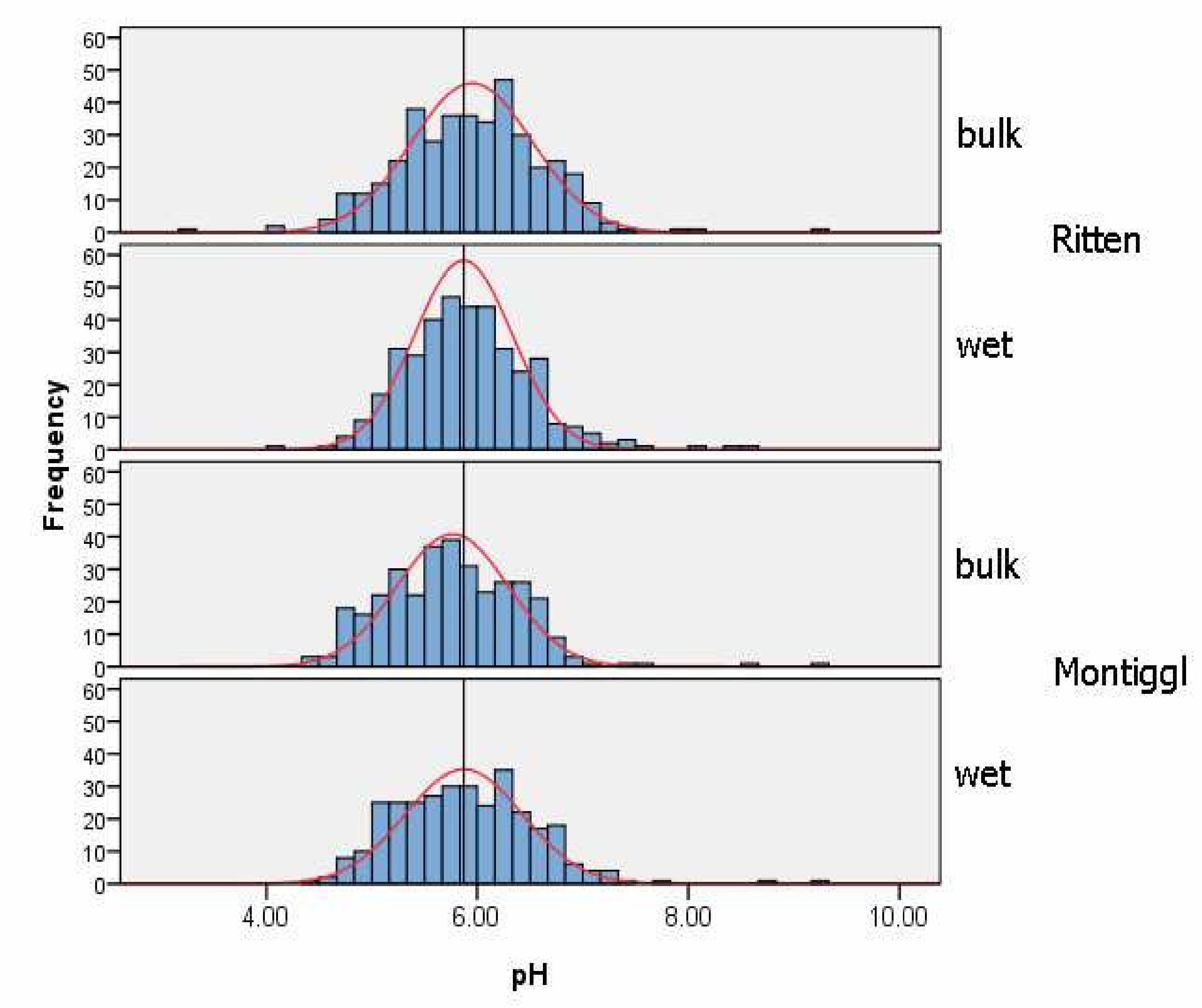


Fig. 2. Distribution of the pH values measured during the period 2002-2011 at the stations Ritten and Montiggl for bulk and wet precipitation and the common median value of 5.86.

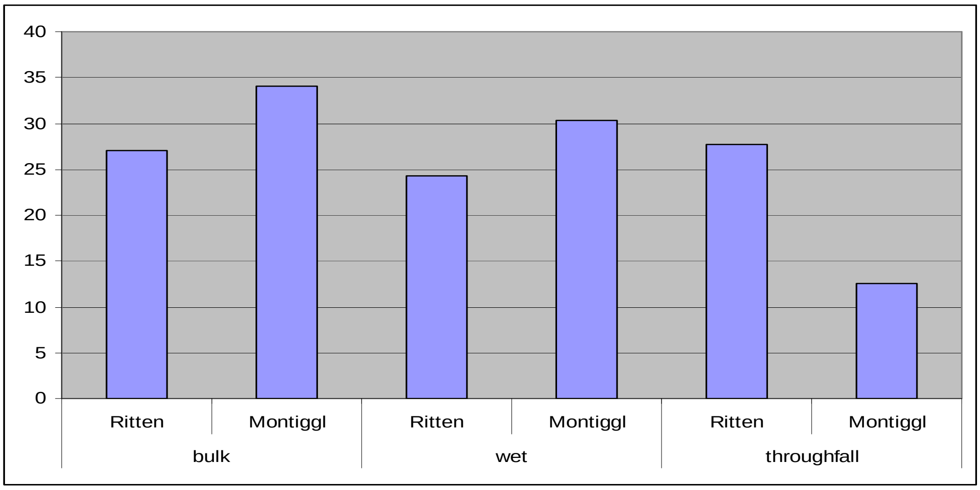


Fig. 3. Percentage of weekly pH values below 5.5 measured during the period 2002-2011. For the values measured under the canopy (throughfall) the difference between the conifer trees at Ritten and the broadleaf forest at Montiggl has to be considered, probably along with a different amount of buffering basic dust.

OPEN FIELD CONCENTRATIONS

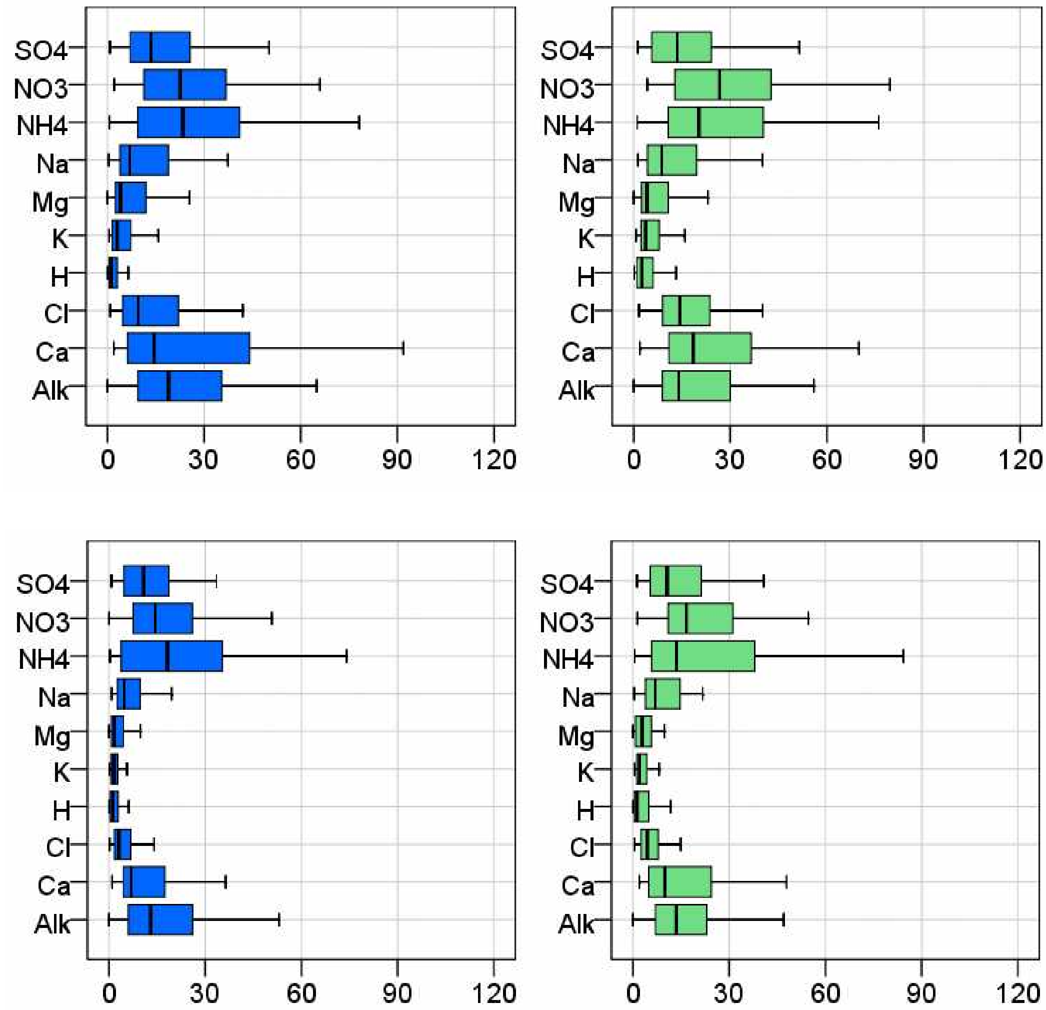


Fig. 4: Weekly open field average concentrations (µeq L^{-1}) during the period 2008-2011. Site of Ritten on the left and Montiggl on the right. Wet values (below) are more representative because less affected by local disturbances.

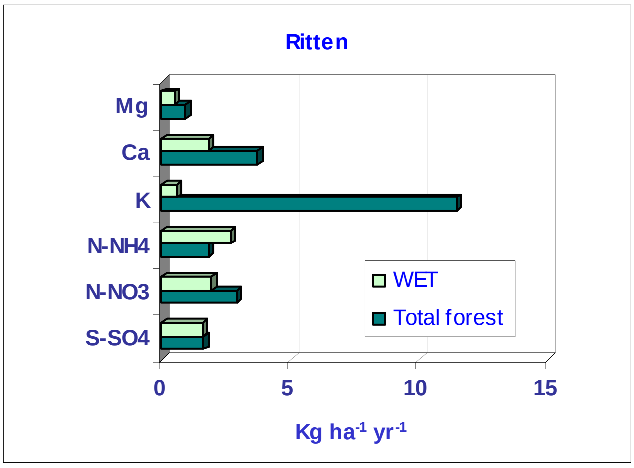
DEPOSITION ON FOREST

Precipitation over a forested ground is altered by the interaction with plant surfaces which act as a filter for airborne gases and particles. This interaction results in a transfer to the forest floor of material captured, washed, and leached from the forest canopy. Hydrogen ion concentration was found to be dependent on tree species, with coniferous canopies decreasing pH and decidous ones increasing pH. Solute concentration values suggest the release of base cations rather than the washout of acidic substances from the foliage and stem of the trees.

Forest site characteristics:

Site	**Ritten/Renon**	**Montiggl/Monticolo**
Latitude (int. system)	46° 35' 20"	46° 25' 37"
Longitude	11° 26' 04”	11° 17' 49”
Altitude (m a.s.l.)	1750	530
Mean annual temperature (°C)	+ 4.1	+ 11,4
Annual precipitation (mm)	970	800
Lithology	quartz porphirit	quartz porphirit
Vegetation zone	subalpine	colline - submountainous
Tree species	Norway spruce, larch, Cembran pine	oak, Scottish pine, sweet chestnut
Understorey species	bilberry	none
Soil type	podzol	acid brown soil

Calcium and magnesium inputs from the stemflow and throughfall were higher than in the bulk samples reflecting the washout and excretion and the sulphate input also exceeded the value for bulk precipitation. Potassium concentrations are much greater in throughfall and stemflow than in wet and bulk precipitation, where concentrations remain low throughout the year. Ammonium inputs from throughfall and stemflow were instead lower than in bulk. Almost no ammonium is present in the soil water. The interaction of the canopy on the nitrogen flow is dependent on its biological activity (time of the year) and on the nitrogen deposition level. An adsorption of the deposited N in the canopy is registered when the deposition level is low, whereas, in more polluted areas, a higher N flow is measured in the throughfall than in the precipitation.



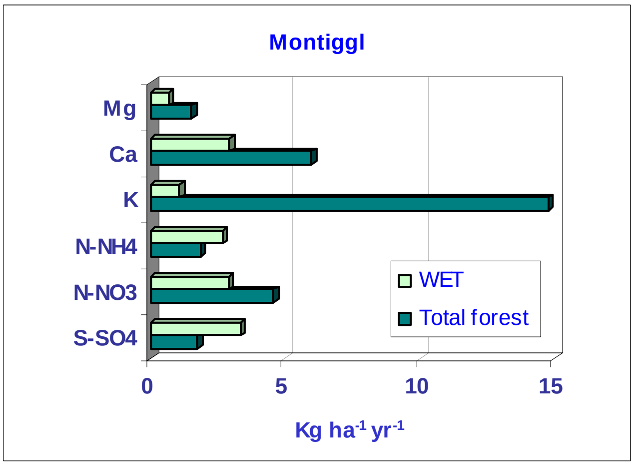


Fig. 5: Total forest deposition to the forest floor is the sum of throughfall and stemflow deposition and contains also the amount of cloudwater input. At both monitored sites the contribution of the stemflow is negligible. Hydrogen ion concentrations in throughfall were higher for the spruce stands (Ritten) than for the oak (Montiggl).

Seasonal variations

The seasonal pattern of precipitation amount is similar among the different precipitation sampling sites and is characterised by higher values during the summer months and much lower volumes during winter.

The monthly precipitation amounts hardly reach 50 mm in the months from December to March, while they easily reach 200 mm at least in one of the summer months. Because of the strong seasonality in precipitation, depositional fluxes are much higher in summer than in winter.

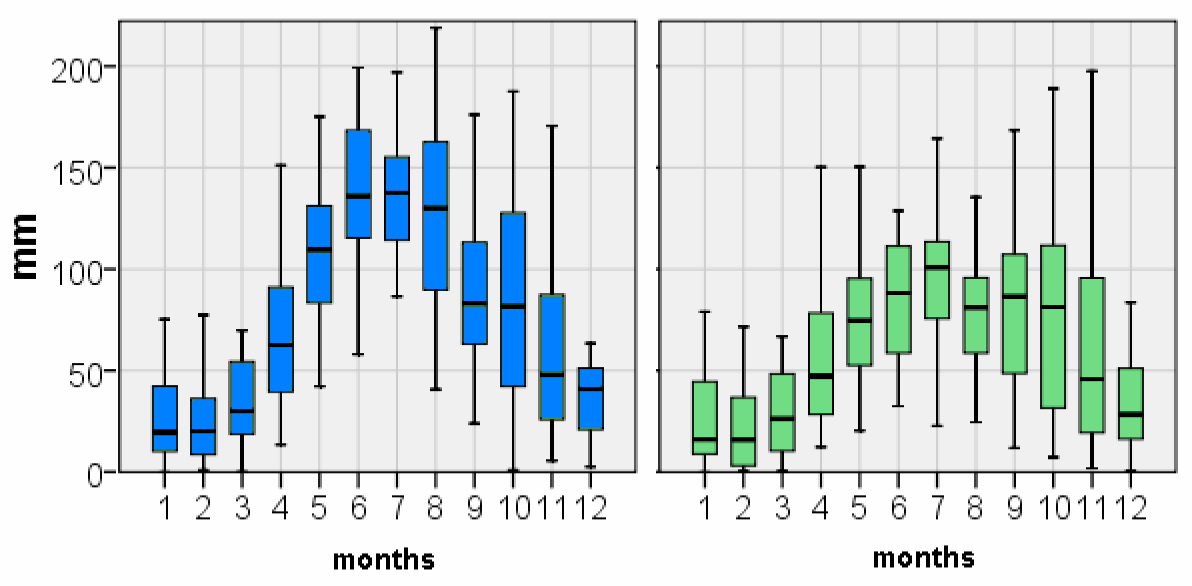


Fig. 9: Monthly precipitation amounts at Ritten (left) and Montiggl during the period 1985–2011.

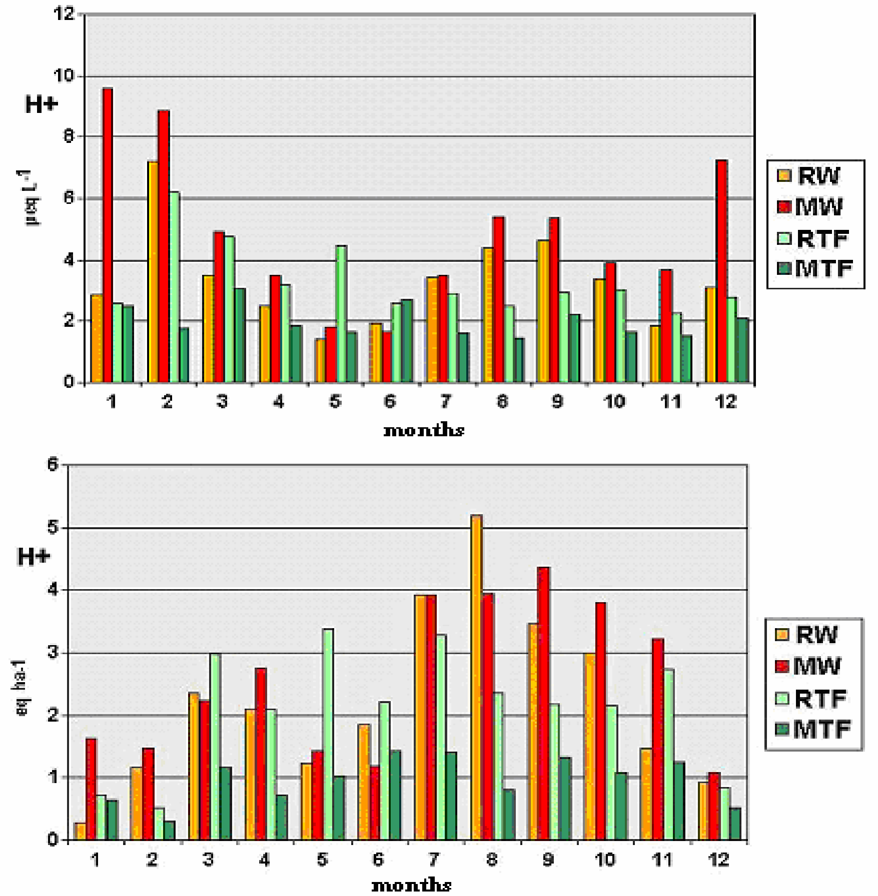
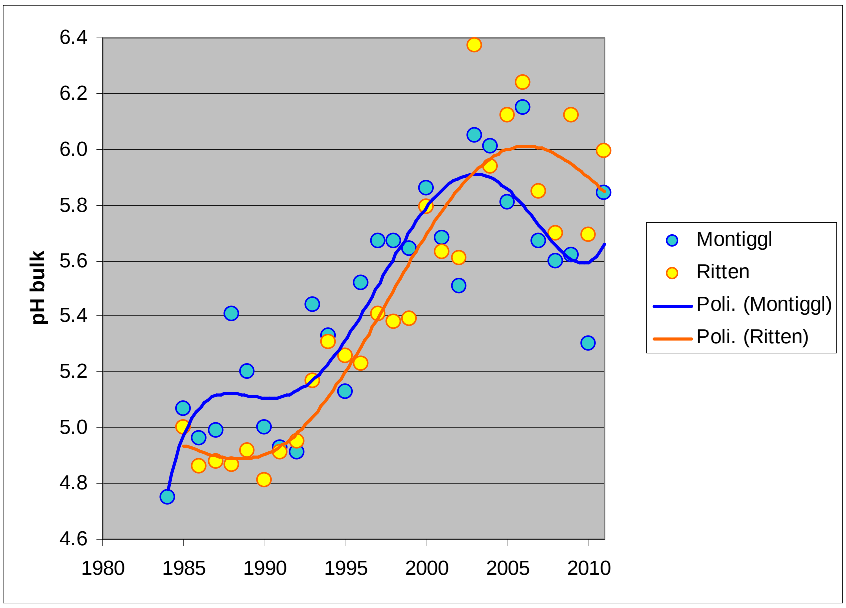


Fig. 10: The strong seasonality of precipitation produces a contrasting distribution of concentrations and depositions.

TRENDS

In Europe sulphur dioxide emissions increased after the post war years and peaked mainly in the 1960s-1970s. Following emission control measures, gradual reductions took place in most countries and especially in Western Europe in the 1980s. During the same period the output of NO_X changed very little. It increased in Europe until the mid 1980s and has since then reduced by around 10%. Industry and power stations have given their contribution to the lowering of emissions, for instance lowering the sulphur fraction of the mineral oil products and implementing desulphurisation plants, but the part due to traffic and agriculture has rather increased, even if the output per vehicle has decreased. Ammonia emissions, coming principally from livestock production and as a reaction product of catalysers showed no significant change. Cleaning up measures and the reduction of the industrial activity in Eastern Europe also led to a reduction in emissions of alkaline dust particles. Although the impact of these reductions on the critical loads is marginal, it can partially counteract the reduction of the acidic input.



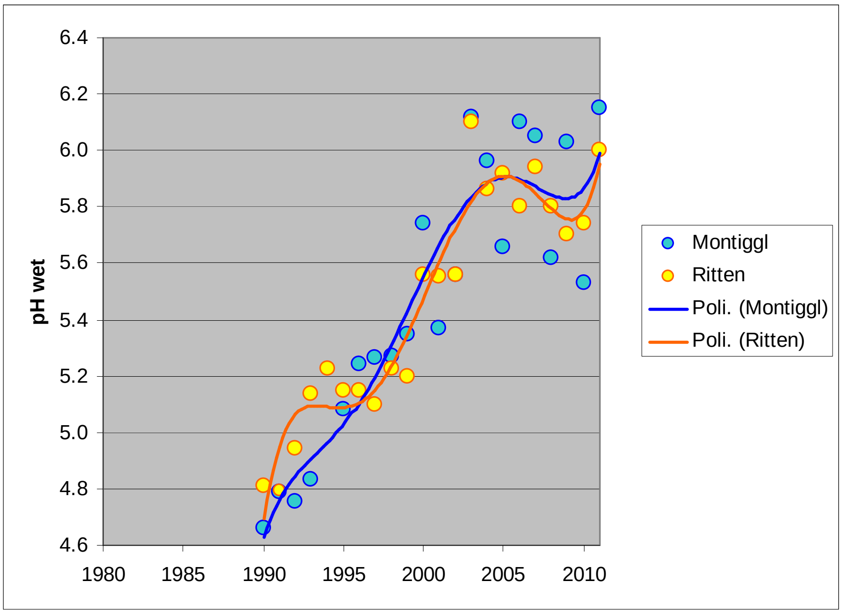


Fig. 11: pH median values measured at the sites Ritten and Montiggl. The acidity of atmospheric precipitation has become lower in recent years.

Reduced sulphur emissions in Europe are leading to decreased atmospheric concentration and deposition levels. These modifications are clearly observable also for the sites in South Tyrol. Atmospheric sulphate levels declined greatly during the last six years, while nitrogen deposition first showed a tendency toward increase up to 1994 and declined only afterwards with a subsequent tendency towards a light increase. The ratio between sulphate and nitrate depositions changed from 2:1 in 1984 to 1:1 in recent years.

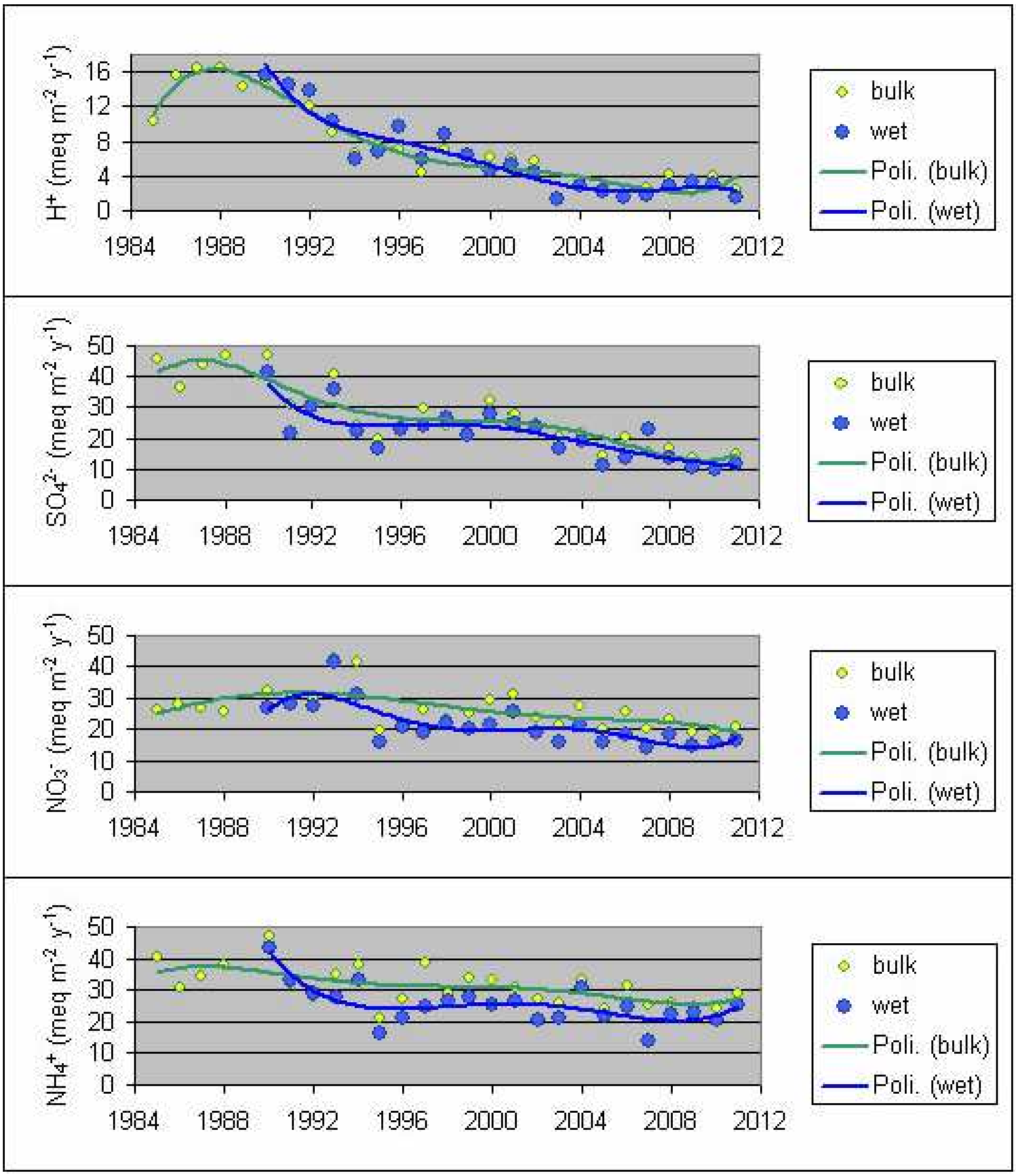


Fig. 12: Annual deposition values calculated from weekly samples taken at the site Ritten/Renon.

QUALITY CONTROL

The analytical methods used, suitable for very soft waters, have been agreed within the research groups involved in European projects (EMEP 1996; ICP IM Programme Centre 1998). The laboratory participates regularly in periodical, national and international intercalibration exercises both for acid rain and freshwater analyses.

METAL DEPOSITION

Transported by atmospheric precipitation heavy metals are deposited on the vegetation and on the ground. The measurement of these toxic elements allows the evaluation of the pollution level of ecosystems. Like the other substances deposited by atmospheric precipitation, metals also follow the local strong seasonality of atmospheric precipitation. Deposition values have been calculated considering only the values lying above the detection limit and could therefore be slightly underestimated, particularly for the metals frequently lying below this threshold. Lead deposition was below the value of 1.5 mg m^{-2} yr^{-1} currently estimated for most parts of Europe (EMEP 2004).

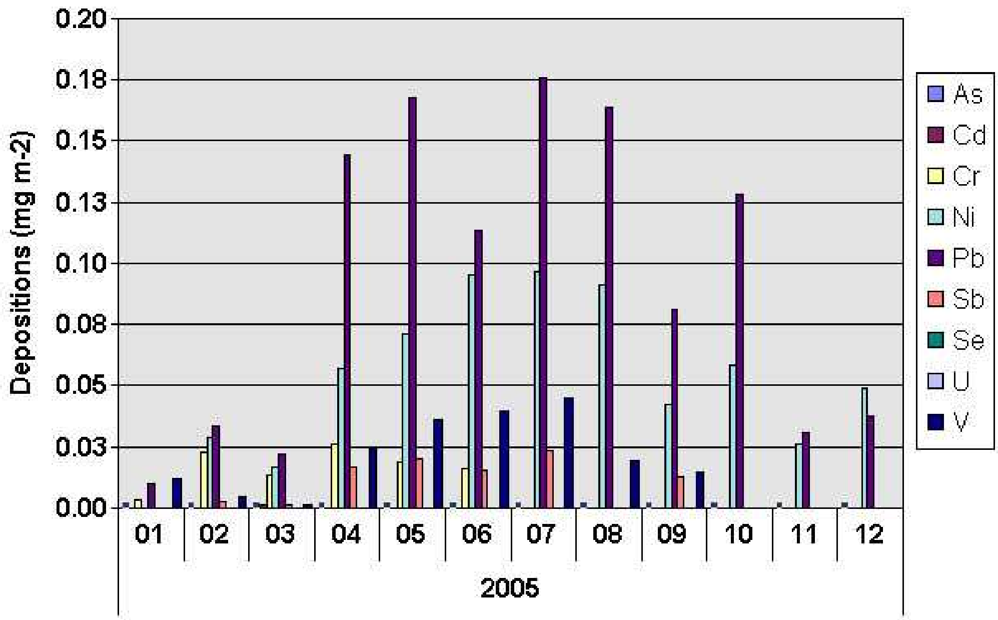


Fig. 6: Monthly deposition values of heavy metals measured for the year 2005.

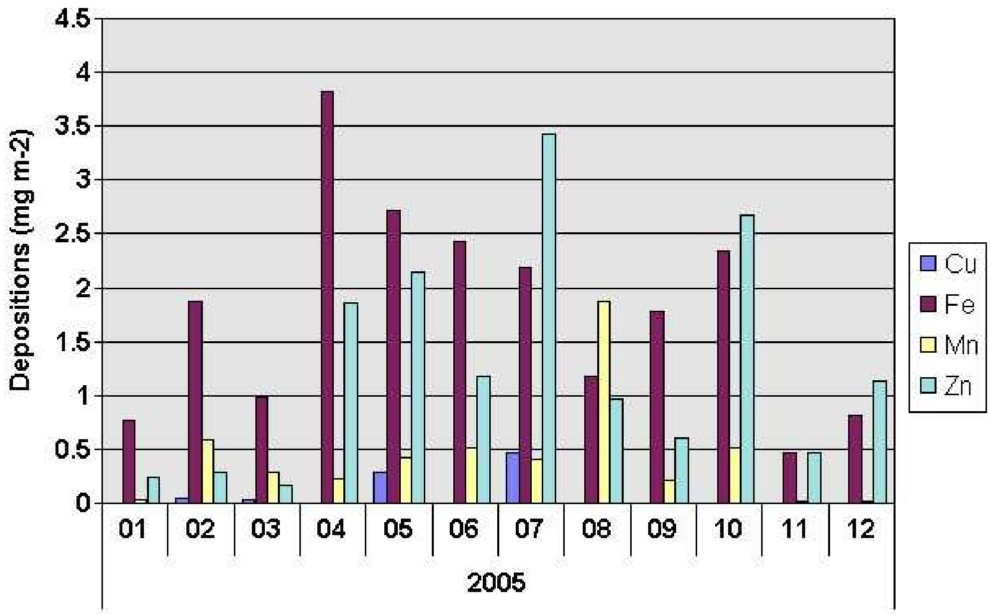


Fig. 7: Monthly deposition values of copper, iron, manganese and zinc measured for the year 2005.

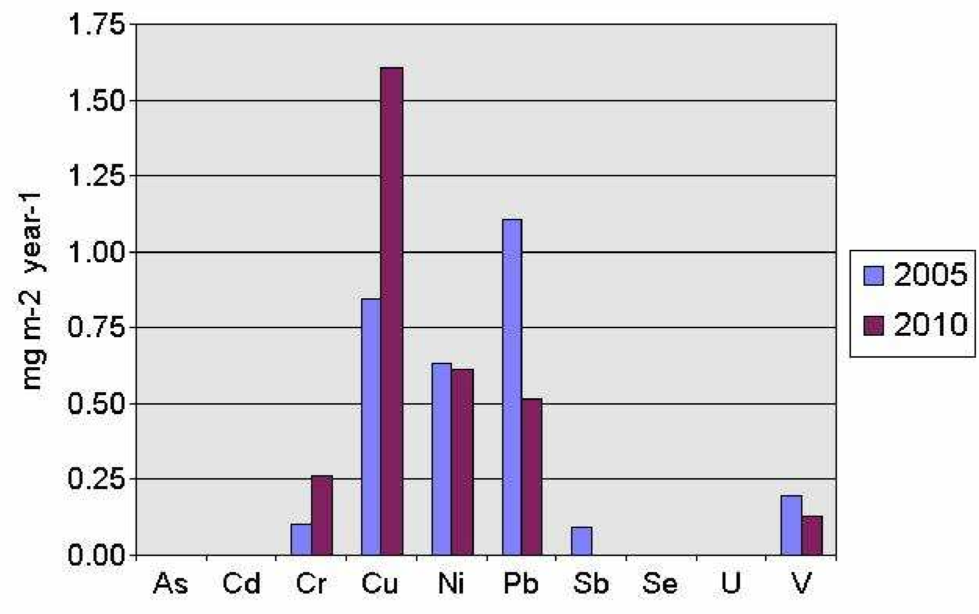


Fig. 8: Yearly metal depositions measured during 2005 and 2010.

PUBLICATIONS

Marchetti, F., D. Tait, P. Ambrosi & S. Minerbi. 2002. **Atmospheric deposition at four forestry sites in the Alpine region of Trentino-South Tyrol**. J. Limnol., 61 (Suppl.1): 148-157.

Tait, D. & B. Thaler. 2000. **Atmospheric deposition and lake chemistry trends at a high mountain site in the Eastern Alps**. J. Limnol., 59: 61-71.

Bendetta, G. 1989. **Schadstoffeintrag durch Niederschläge in Südtirol**. Proc. 14th Int. Meeting for Specialists in Air Pollution Effects on Forest Ecosystems, IUFRO P2.05: 387-389.

Bendetta, G. 1987. **Alterazioni ambientali dovute all'inquinamento atmosferico.** Annali Lab. Biol. Prov. Aut. Bolzano, 4: 387-389.