Tree rings serve as an indicator for climate, soil conditions, health status of trees, etc. and are an absolute basis for dating. Over several decades scientists believed, that tree rings serve as an indicator for trends in air pollution. Our study shows that this is an invalid simplification. Most of the previous studies were performed on trees in soils, which suffered from rising acidification (pH drop) and heavy metal contents caused by atmospheric input. Contrary to previous examinations, we analyzed year rings from 2 oak trees growing on soils with continuously increasing pH-values since 1896. Our results show element trends modifying previous interpretations.

Material and methods
Two oak trees (Quercus robur L.) were felled in 1993, 10km east of Hannover (Germany). 18 and 150m away from a highly frequented freeway (cars per day: 1936: 3000; 1970: 33000; 1990: 57000). Single tree rings were sampled from trunks at 1.4 m height and analysed by ICP-MS and ICP-OES after complete digestion by a HNO3-HClO4-HF mixture under clean lab conditions. The growth rings comprise the years 1913-1992 and 1852-1992 respectively. The soil near the freeway is a loamy cambisol with pH-values of 5.9 (Ah horizon) and 6.2 (Bv: 0.18-0.44m). The soil distant to the freeway is a gleysol with pH-values of 6.9 (Ah) and 7.1 (G: 0.10-0.47m). Since 1896 both forest soils received basic emissions from a cement factory nearby, increasing systematically the pH values from around 4 up to 7.

Constraints for year rings as indicators for air pollution
Several conditions have to be fulfilled to reconstruct a relative air pollution history from annual tree rings:
1. Only contaminants from the air intercepted by leaves/needles and bark should be incorporated into tree rings.
2. Contaminants from soils should not be accumulated in the rings, because soils represent a reservoir with growing amounts of pollutants.
3. The pollutants of a certain year should be incorporated in the corresponding year ring.
4. After the formation of a tree ring, no further translocation of pollutants between the rings or in vertical direction should occur.
5. During the formation of heartwood (addition of resins, gums, tannins etc.) no further change of the pollutant chemistry should occur.
6. The accumulation of a pollutant should be independent of the tree ring width.

Element fluxes in trees:
According to Braun (1982) only the 2 youngest annual rings conduct water. An exchange of elements between adjoining growth ring should be minimal. Therefore we chose oak trees for our investigations.

Our data show, that many assumptions from above are not accomplished:
1. The elements Li, K, Rb, Cs, Ti, Mg, Ca, Sr, Ba, Mn, Co, Ni, Cu, Zn, Cd, Ag, Mo, P, Y, and La give evidence of redistribution inside the sapwood and in the transition area between sapwood and heartwood (figure 1). Ti, Cr, Sn, Ag, Pb, and Sb were not translocated.
2. Concentrations of Li, Ca, Sr, Ba, Co, Ni, Cu, Zn, Cd, Pb, Ag, Mo, Sb, Ti, Y, and La decrease with increasing tree ring width.
3. Positive correlations exist between the amount of precipitation and the contents of Rb, Cs, Ca, Sr, Co, Ni, Cu, Zn, Sb, Sn, Y, and La in year rings.
4. With rising soil pH from about 4 up to 7 over the years, the contents of Mn, Mg, and partially of Ba in the tree rings decreased (figure 2). The Sr contents rose, consistent with increasing mobility of anionic Sr-species with increasing pH. Under favourable conditions these elements may serve as indicators for the development of soil pH over time.
5. The indicators for traffic emissions such as Pb, Cd, Zn, Cr, Ni, and Cu in tree rings do not correlate with growing emissions by traffic, industries and households. These elements usually are supplied from the soil. In our soils the transfer of these cationic heavy metals was suppressed by the rising pH-values. If lead within the tree rings (figure 3) would be supplied by air pollution, the real trend of Pb should approximately follow the annual deposition rate of Pb in Germany (figure 4), what is evidently not the case.

Summary:
We assume that the positive correlation between heavy metals and air/soil pollution, as measured by many authors, are primarily caused by enrichment of heavy metals in soils and the simultaneously rising acidification, which facilitates the uptake of the cationic metals by plants. In summary, many interrelated factors determine element contents in tree rings such as soil pH and composition, cation exchange capacity, interception and leaching of pollutants from leaves/needles, climate, growth rate, redistribution of elements, etc. Air or soil pollution chronologies by tree rings are ill-founded. Under very favourable conditions the acidification history of soils can be reconstructed by the contents of Mn, Mg and Ba in tree rings.

References: