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Air Quality Survey Carried Out by Schoolchildren: An Innovative Tool for Urban Planning

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Abstract An educational project on biological monitoring of air quality was launched in 2004 to involve about 650 young students (age 6 to 16) from 21 schools of nine municipalities in Tuscany (Central Italy) in active detection of the crucial pollutant ozone with indicator sensitive tobacco seedlings. Results implied the reading of 9,300 raw biological figures and were fortified by the data captured by six photometric analysers. Under the guidance of their teachers, the students had several opportunities to practice with many basic and applied study areas and were initiated into the scientific method in a simple and absorbing manner. Curiosity and involvement were widespread; a sort of emotional and responsible relationship was developed by several pupils. Though primarily an educational exercise, the survey introduced a research element and the regional picture of air pollution that emerged has increased our knowledge of the air quality situation in the area. Biological monitoring of air quality is a powerful tool to improve the awareness and involvement in key topics of environmental education. In addition, it represents a crucial element for improving the awareness of problems and implies the active participation of citizens in the assessment of several indicators of the state of the environment. Its potential as a robust implement in landscape and urban planning is noteworthy.

Keywords Air pollution · Biomonitoring · Environmental education · Environmental quality · Indicator plants · Ozone · Tobacco

1 Introduction

Urban environmental quality is a key but complex concept, resulting from both anthropogenic and natural factors at different spatial and temporal scales. Air quality is likely to be the environmental issue of most concern in the future (Beaumont, Hamilton, Machin, Perks & Williams, 1999) and the detrimental effects of air pollution on human health and welfare are well known (Brimblecombe, 2003; Brimblecombe & Maynard, 2001; Emberson, Ashmore, & Murray, 2003). So, for instance, a report of the World Health Organization, which looked at vehicular emissions in three European countries, revealed that more people were killed prematurely by the effects of pollutants than through car accidents (WHO, 1999). Tropospheric ('ground level') ozone is the major air quality problem of nowadays in most developed countries,

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not only in urban areas (where the greatest production takes place, starting from precursors such as nitrogen oxides and non-methane hydrocarbons), but also in rural and remote localities, due to natural atmospheric transport. Man-related air mixing ratios of ozone are increasing and several impacts on human life and welfare are expected, such as adverse health effects, damage to manufactured items and materials, injury to plants, reduced visibility, and a contribution to the 'greenhouse effect' (Colbeck & MacKenzie, 1994). As combustion processes due to vehicular traffic represent the major source of ozone precursors, the only realistic way to minimize the presence of this pollutant in the air is to reduce drastically traffic levels. This implies several deep modifications in the mobility habits of many people. A large popular consensus should be reached by decision makers to overcome traditional resistance to such initiatives.

Biological monitoring may be defined as the measurement of the response of living organisms to changes in their environment. As a rule, plants are more sensitive (in terms of physiological reaction) to the most prevalent air pollutants (such as ozone) than humans and animals. This methodology may be performed through observations and analyses of the native and cultivated vegetation present in a given study area (so-called 'passive monitoring') or carried out with selected test plants of standard genetic origin and developmental state, which are exposed to ambient air under standardized conditions ('active monitoring'). Biomonitoring may allow a detailed and reliable coverage of the territory with relatively low costs, it does not require an electrical supply and its educational and didactical values are incomparable. These techniques provide information on the response of living organisms to the integrated effects of environment and contamination which cannot be determined by direct analytical measurements. An ideal indicator plant must satisfy some key requirements, such as: (1) to be very sensitive to a specific pollutant and then to have a low threshold for visible injury (the reaction must occur quickly when exposed to realistic pollutant concentrations); (2) the visible response should be precise, characteristic, possibly specific and definitively reproducible; (3) the intensity of visible response must be easily quantified and an appropriated calibration procedure against the actual pollutant doses must be possible; this allows the extrapolation of pollution levels from biological data; (4) the indicator should have an adequate period of vegetation and be easily cultivable, well adapted to the environment and tolerant to the major stress factors, both of biotic (pests, parasites) and abiotic (thermal extremes, water deficit, other chemical pollutants) nature. The final goal of biomonitoring is not to replace the conventional physico-chemical approach: an integration of the two systems is the most appropriate solution for air quality assessment.

Air pollution biomonitoring is a research approach with long history. Many research groups have used biomonitoring as a powerful, cost effective, user friendly, tool for filling the gap between the causes and effects of environmental pollutants, as bioindication agents assess the cumulative effects of pollution (Saitanis, 2003; Saitanis & Karandinos, 2001; Saitanis, Katsaras, Riga-Karandinos, Lekkas, & Arapis, 2004; Tonneijck & Posthumus, 1987).

A useful application can be the setting up of biomonitoring campaigns with school children (Castell & Maronnier, 2002; Lorenzini & Nali, 2004). This paper describes a set of pilot studies aimed at involving several schools in mapping air quality by means of indicator plants in a large territory of Tuscany, central Italy. A preliminary and partial presentation of some results has been already given (Nali, Catoni, & Lorenzini, 2006).

2 Materials and Methods

Three simultaneous and coordinated pilot studies were performed in the spring 2004, involving 21 schools (and 34 classrooms), covering nine municipalities in the districts of Livorno and Pisa (Figure 1). The surface covered was about 625 km^2, and was populated by some 305,000 inhabitants. Elevation ranged from 5 to 200 m a.s.l. Altogether, about 650 children were involved in the project, their grade range spanning from elementary schools (6–10 years), to junior secondary (11–13 years), up to grammar schools (14–16 years). Approximately half of them were rural and half were urban pupils. In April 2004, a series of preliminary seminars was given to the teachers; didactical material (in the form of published literature on the topic, a specific CD-ROM and an operational manual, inclusive of an estimation catalogue with colour specimen photos) was described and given. Special attention was devoted to give a

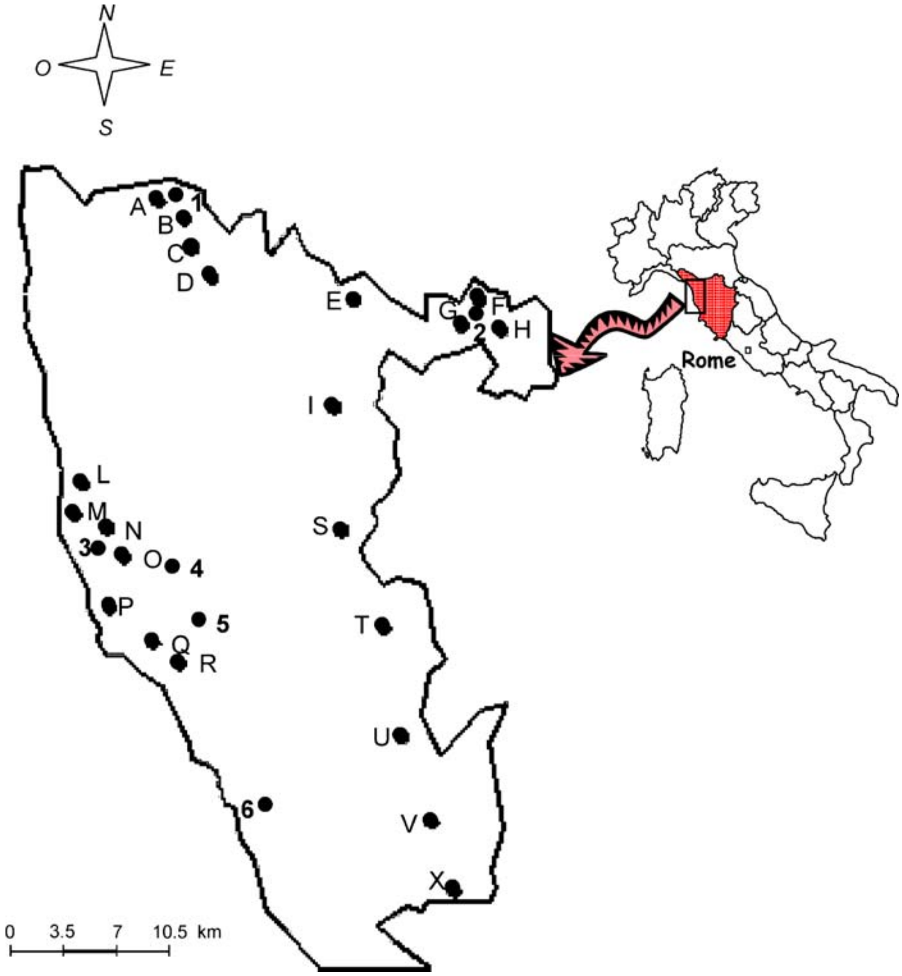

Figure 1 Map of the area investigated showing the location of the schools and of the photometric analysers of ozone. *A* ITIS Da Vinci; *B* SMS Fucini; *C* ITC Pacinotti; *D* SMS Gamerra; *E* ITC Pesenti; *F* ITIS Marconi; *G* IPSIA Pacinotti; *H* Linguistico Montale; *I* SE Cenaia; *L* SMS Borsi; *M* SMS Pazzini; *N* SE Razzauti; *O* SMS Mazzini; *P* SE Banditella; *Q* SE Noolt; *R* SE Montenero; *S* SE Lorenzana; *T* SE S. Luce; *U* SMS Castellina; *V* SMS Riparbella; *X* SMS Montescudaio; *1* Passi (Pisa); *2* Misericordia (Pontedera); *3* Cappiello (Livorno); *4* Maurogordato (Livorno); *5* Gabbro (Rosignano Marittimo); *6* Rossa (Rosignano Marittimo).

proper information to students (and teachers) on the differences between stratospheric ozone ('good ozone') and photochemically produced tropospheric ozone ('bad ozone').

An *ad hoc* internet forum was set up in a specific web site http://www.biomonitoraggio.org) and a discussion group activated. Teachers were encouraged to describe the features of the experiment to their pupils in a clear and plain way; frequently asked questions were collected and an expert from the University of Pisa was available for online help.

Ready-to-use miniaturised kits (Lorenzini, 1994) based on germlings of tobacco (*Nicotiana tabacum* L.) cultivars Bel-W3 (ozone supersensitive) and Bel-B (ozone-resistant) were delivered on May 10 and 24, 2004, and exposed to ambient air (under a shading net) for 7 days. The entire methodology, from sowing to visible injury evaluation (minute bifacial necrotic spots on cotyledons and leaves) was coded by the Italian Agency for Environmental Protection (ANPA, 1999). Seedlings were raised in a controlled environment, charcoal-filtered air ventilated facility. The symptoms were evaluated every other day, but only results captured at the seventh day are reported here. The assessment of the plants took place according to the same methods used in our reported experiments (Lorenzini & Nali, 2004): symptoms on cotyledons were assessed by means of a hand lens, according to a 1-to-5 scale, and recorded on standard data sheets. All of the pupils were allowed to express their evaluation and the final judgement for each sample was averaged out by the teacher. The final readings were also performed independently by three selected and experienced operators and their values averaged and regarded as the truth. A bulk of some 9,300 cotyledons was read and relative data (in terms of Cotyledonar

Injury Index, CII) processed. Correlation analysis and determination coefficient were computed between CIIs given by classrooms and reference values given by expert evaluation team.

The actual ozone concentration in the study area during the campaign was measured by six automatic photometric analysers run by local environmental authorities; their location is also reported in Figure 1. Raw data (in terms of hourly ozone averages) were processed to describe the typical day and compute the AOT40s (Accumulated exposure Over a Threshold of 40 ppb – Nali, Pucciariello, & Lorenzini, 2002a) and the M1 (maximum daily hourly means – Nali, Pucciariello, & Lorenzini, 2002b). All ozone data are expressed in ppb (or ppm), in volume; for ozone, 1 ppb is 1.96 μg m^{-3} at standard temperature and pressure. Meteorological conditions during the experiment were monitored at the station of Livorno-Via De Sanctis. Two-dimensional zone maps of CII of operators and AOT40 values were drawn using the Surfer plotting program, which transforms discrete data into a continuous distributional model,

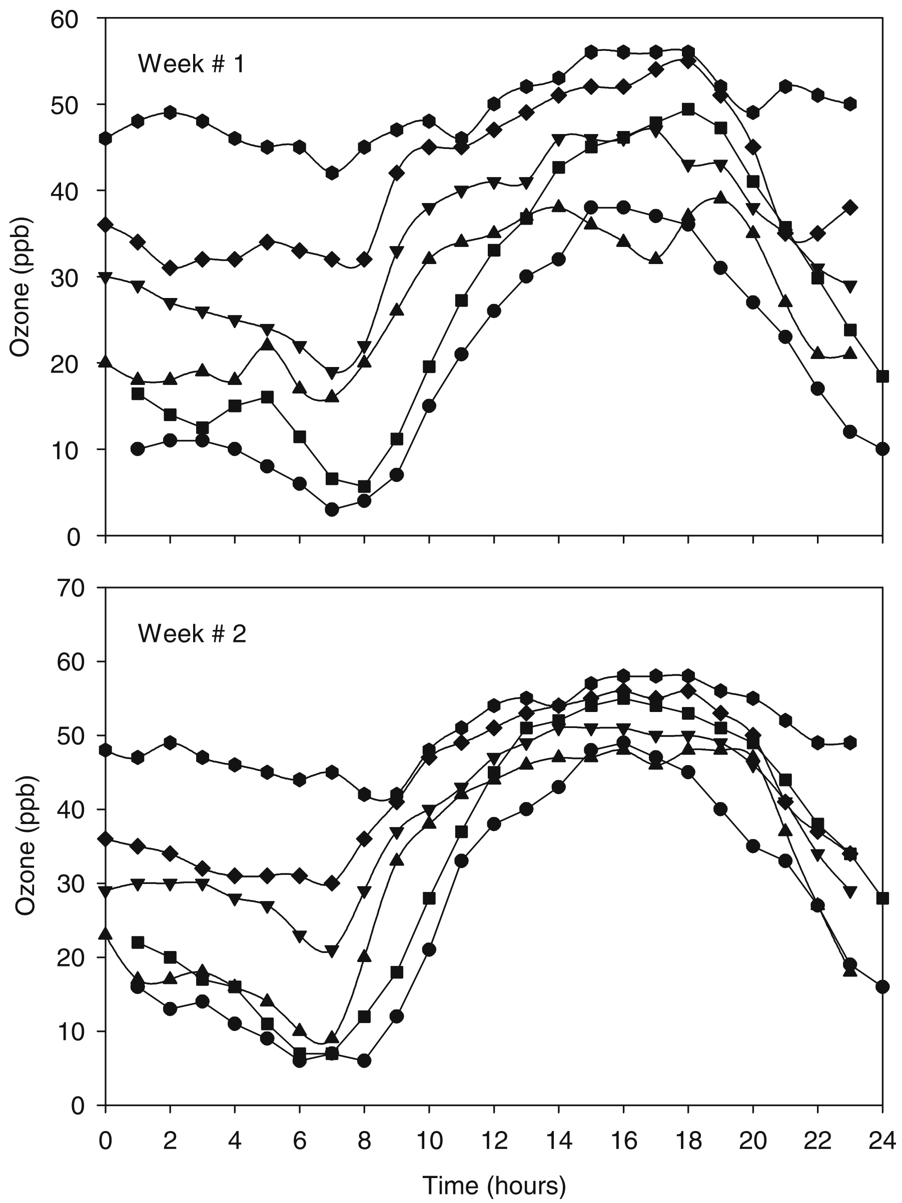

Figure 2 Ozone average diurnal profiles for the period 10 to 16 (week # 1) and 17 to 23 May (week # 2), 2004 from the automatic analysers.
●, Misericordia (Pontedera);
■, Passi (Pisa);
▲, Rossa (Rosignano Marittimo);
▼, Cappiello (Livorno);
♦, Maurogordato (Livorno);
⬢, Gabbro (Rosignano Marittimo).

using kriging (geostatic autocorrelation of the nearest randomly placed value to produce an estimate of minimum least squares variance) as the interpolation algorithm (Olea, 1974). Ozone concentration correlated to biological data was related to all the days of exposure less one (this because the ripening of lesions induced by ozone requires 24 h, Heggestad, 1991). Correlation analysis and determination coefficient were computed between CIIs given by expert evaluation team and AOT40 values.

The reproducibility (i.e., the concordance of the estimates of pupils and of expert evaluation team) was evaluated using k statistics (Cohen, 1960). The coefficient of agreement k is the proportion of chance-expected disagreements which do not occur or, alternatively, it is the proportion of agreement after chance agreement is removed from consideration:

$$k = \frac{p_0 - p_c}{1 - p_c}$$

where: p_0=the proportion of units in which the scorers agreed; p_c=the proportion of units for which agreement is expected by chance. When the obtained agreement equals chance agreement, then k=0. Greater than chance agreement leads to positive values of k. The upper limit is 1, this occurs when there is perfect agreement among scorers. To test for significance of an obtained k, a z statistic is used:

$$z = \frac{k}{\sqrt{\mathrm{var}(k)}}$$

In order to maintain consistent nomenclature when describing the relative strength of agreement associated with k statistics, the following labels were assigned to the corresponding ranges of k (Landis & Koch, 1977): k=0, poor; k=0.01–0.20, slight; k=0.21–0.40, fair; k=0.41–0.60, moderate; k=0.61–0.80, substantial; k=0.81–1.00, almost perfect.

3 Results

The meteorological conditions during the study period (May 10–24, 2005) were consistent with the historical averages for the period 1951–1998. Figure 2 shows the typical bell-shaped diurnal profile of ozone levels in the six stations where the analysers were present during the two weeks of the present study; this is due to the dependence of ozone formation on the presence of solar radiation (Colbeck & MacKenzie, 1994). AOT40s and M1 values are reported in Table I.

Due to the described relevant ozone levels which occurred in Tuscany in the late spring of 2004, all the sensitive Bel-W3 tobacco seedlings showed typical bifacial necrotic symptoms after a few days of exposure to ambient air in all the exposure sites. The response was fast and spectacular and surprised the pupils. No deleterious effect was observed on the resistant Bel-B material, whose threshold of sensitivity is quite high (Heggestad, 1991). In total, 194 out of the 204 kits delivered have been successfully scored. Three classrooms did not complete the experiment, due to external circumstances (e.g., thunderstorm damage or poor maintenance of plants).

In many cases, the standard deviation of the average score was very high due to the large variability of single scores expressed by each pupil. Figure 3 summarizes the average results given by each classroom, in comparison to the assessments given by the expert team. Twenty-one classrooms (33.3% of elementary, 42.9% of junior secondary and 77.8% of grammar schools) gave results within a range of plus or minus 30% in comparison with the reference score. It appears that most of the results given by the students are severe underestimations of the truth. This is true for the first week, but not for the second one: it is possible that students were skilled from the first week and they utilized their experience

Table I AOT40s (in ppb h) and maximum hourly means (M1, in ppb) for ozone in the six stations were photometric analysers were operating, in the period 10 to 16 (week # 1) and 17 to 23 May (week # 2), 2004

Station	AOT40		M1	
	Week # 1	Week # 2	Week # 1	Week # 2
Passi (Pisa)	100	105	56	52
Misericordia (Pontedera)	271	237	56	52
Cappiello (Livorno)	1008	1306	76	67
Maurogordato (Livorno)	974	1113	72	63
Gabbro (Rosignano Marittimo)	2793	2720	89	78
Rossa (Rosignano Marittimo)	367	535	67	58

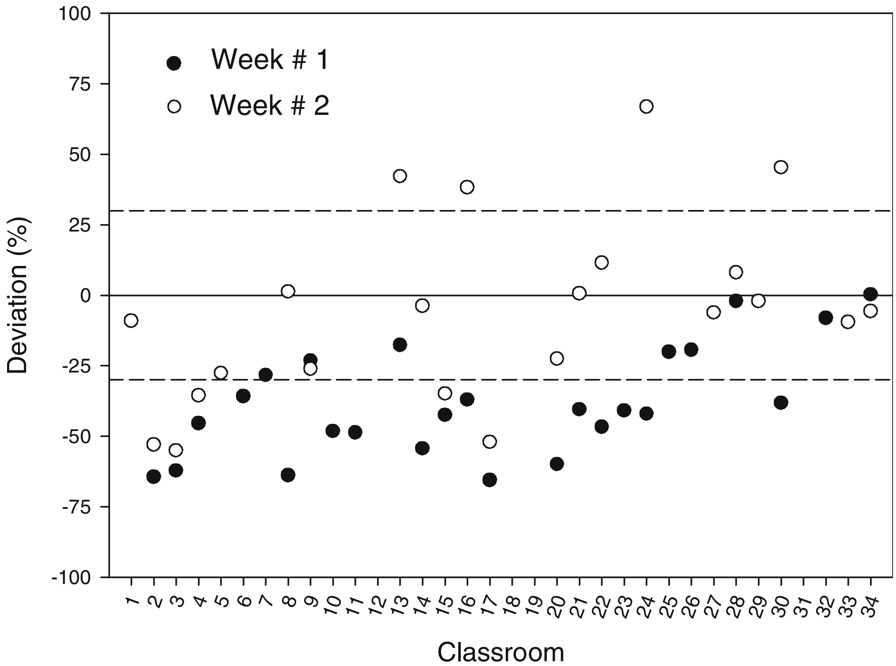

Figure 3 Relative scattered distribution of the average Cotyledonar Injury Index reported by each classroom from the actual figure detected by the expert team. Classrooms coded from 1 to 16 are elementary schools; from 17 to 27 are junior secondary; from 28 to 34 are grammar schools.

and improved their estimation during the second week. The risks linked to the low reliability of the visual assessment of ozone symptoms performed by inexperienced personnel have already been analysed (Lorenzini, Nali, Dota, & Martorana, 2000). Disaggregation of deviations from the true values was performed on a type-of-school basis (Table II). Relevant association between CIIs given by classrooms and reference values given by expert evaluation team are observed for junior secondary and grammar schools. Figure 4 shows the CIIs in all the classrooms of the elementary, junior secondary and grammar schools in comparison with ones calculated by operators. Median value of the grammar classrooms was the same as the reference team; median values of elementary and junior secondary classrooms were about twice and half as much again than those of reference team, respectively.

On the whole, the bulk of the responses highlighted a quite low level of accuracy but an acceptable level of reproducibility (Table III). The dominance of underestimation may be mainly attributed to the incapability of detecting symptoms on cotyledons: it must be stressed that the average size of such cotyledons was a mere $6-7\times4-5$ mm and the lesions to be detected in the form of discoloration were only a few millimetres wide, or even less. Most of the students were unfamiliar with the use of a hand lens.The processing of all of the

Table II School-related deviations of scores of Cotyledonar Injury Index of tobacco Bel-W3 seedlings with respect to the actual values as determined by the reference team

Type of school	Percentage of classrooms with significant underestimation of scores	Percentage of classrooms with significant overestimation of scores	Correlation between scores given by classrooms vs truth as given by the expert evaluation team
Elementary	58	8	$y = -0.504 + 0.073\,x$ $R^2<0.40$
Junior secondary	50	7	$y = 1.358 + 0.115\,x$ $R^2=0.55$
Grammar	11	11	$y = 0.577 + 0.273\,x$ $R^2=0.50$

Scores within ±30% from the actual data were regarded as ‘correct’. R^2 is the determination coefficient.

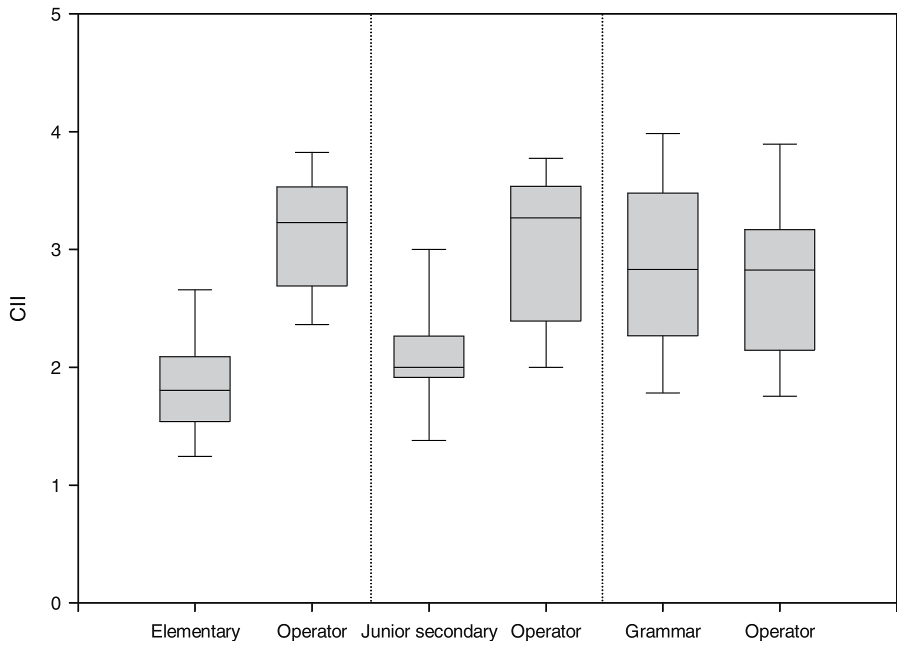

Figure 4 *Box* and *whiskers* representation of CIIs of schools in comparison with those of experienced team. Each *box* encloses the 25th, 50th (median) and 75th percentiles of the concentrations; *whiskers above* and *below* the *box* indicate the 90th and 10th percentiles, respectively.

validated data by the expert team allowed the creation of two thematic charts, which describe the spatial distribution of CIIs in the two weeks of investigation (Figure 5). Progressive AOT40s were correlated to concomitant readings of symptoms on indicator plants shifted by one day, to allow the ripening of lesions (AOT40 vs CIIoperators, $y = 0.0003x + 2.8179$, $R^2 = 0.41$, and $y = 0.0002x + 2.3347$, $R^2 = 0.45$, for week 1 and 2, respectively).

Table III Values of *k*, as a measure of reproducibility of the estimates of pupils in comparison to expert evaluation team ones

Type of school	School	*k*	Strenght of agreement
Primary	Noolt	0.31	Fair
	Montenero	0.26	Fair
	Montescudaio 2	0.22	Fair
	Razzauti 3A	0.20	Slight
	Razzauti 4A	0.20	Slight
Junior secondary	Gamerra	0,02	Slight
	Mazzini 2 L	0.44	Moderate
	Pazzini 1 I	0.18	Slight
	Pazzini 1 L	0.26	Fair
Grammar	Da Vinci	0.37	Fair
	Pacinotti	0.23	Fair
	Montale	0.16	Slight

4 Discussion and Conclusive Remarkings

Ozone was confirmed to be a significant presence in all the area investigated, both in urban and in rural areas. This is not surprising, as it is clear that the geographical and climatic context of Tuscany is favourable to significant high levels of photochemically produced ozone (Nali, Ferretti, Pellegrini, & Lorenzini, 2001).

The project was a success on the educational plan and reached its aims, which were those to allow students (but also families and teachers) to have a first-hand experience of how polluted is their aerial environment, by using an extraordinary and reliable tool, such as biological monitoring. So, pupils and their relatives were the witnesses (and main actors playing a decisive role) of an inexperienced form of monitoring, on the basis of simple but scientifically sound procedures. By means of periodic press releases, local media underlined the importance of this innovative approach to evaluating the state of health of the environment. Some schools set up poster exhibitions describing their experiments. Several students proudly took pictures and videotapes with their cameras; some of them appeared to have developed a long lasting interest in environmental sciences. A special 1-day event was celebrated at the Faculty of Agricultural Sciences of the University of Pisa to give

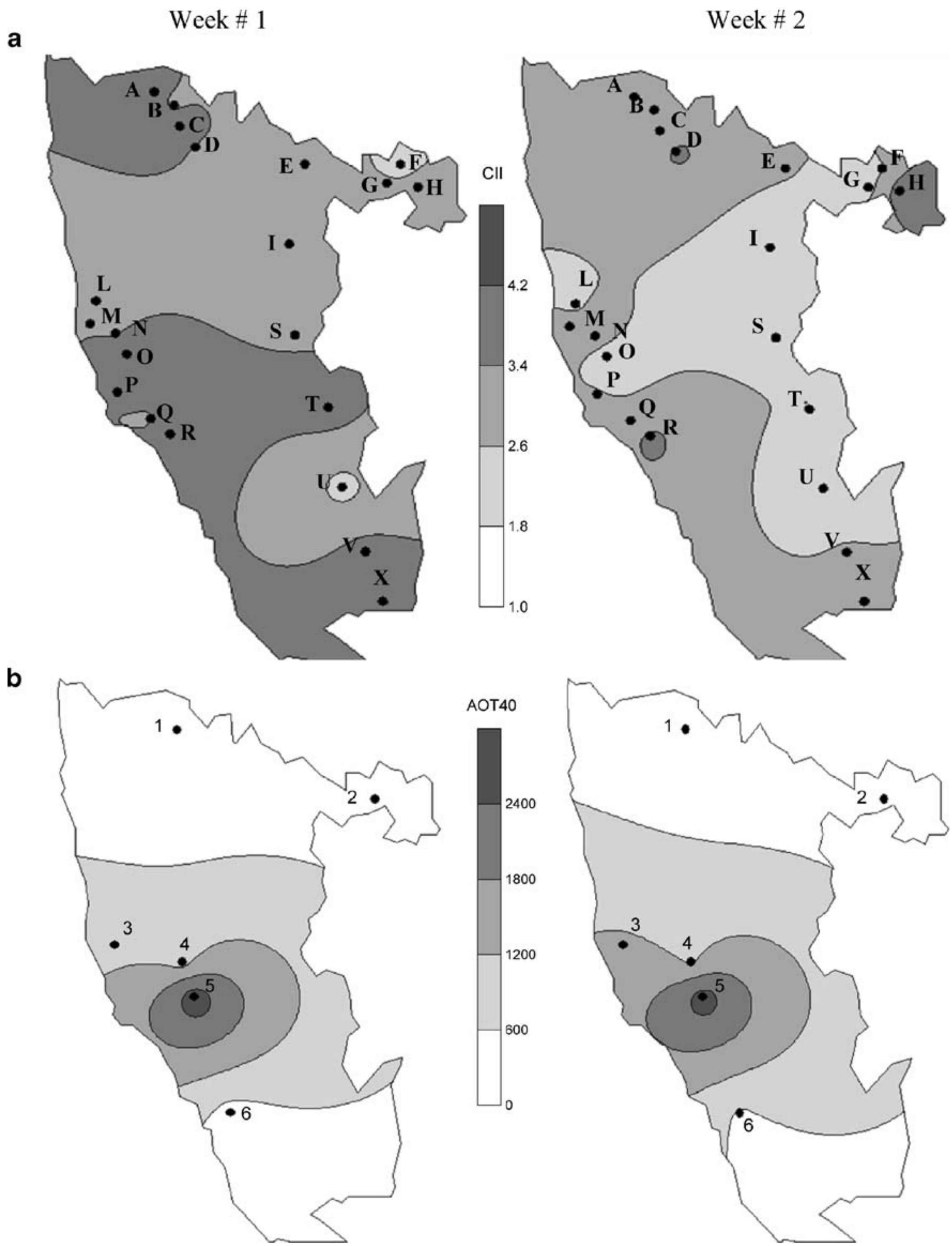

Figure 5 Spatial distribution of the Cotyledonar Injury Index (*CII*, on a 1–5 scale) on tobacco Bel-W3 (ozone supersensitive) seedlings (based on data recovered by the experienced team) (a) and of AOT40 (ppb h) (b) in the study area.

official results to mass media and policy makers (for further details, see http://www.biomonitoraggio.org).

Ozone monitoring is an environmental priority, but conventional chemico-physical analysers are scarce, due to their cost of purchasing and maintenance. Photooxidant contamination in the Tuscany appears to be significant and the critical levels established by UN/ECE (Directive 2002/3/EC, Official Journal L 67, March 9, 2002) are exceeded. The values observed in this experiment should not be regarded as the worst possible scenario, as they were collected at the mere beginning of the photochemical season; in spite of this, they should be associated with relevant negative effects on cultivated and natural vegetation. Meeting air quality objectives for ozone, nitrogen and carbon oxides and suspended particulate matter usually requires viable solutions that have at their core measures that mean a rethinking of mobility habits. Environmental education study cases such as the one described here may become a tool for nurturing environmental ethics and for instilling prudent attitudes and practises towards nature, its state of health and its limited resources.

The use of the miniaturized kit described here is a solid example of good science, reliable, specific, quick, very cost-efficient and easy to manage (Toncelli & Lorenzini, 1999). The kit represents an original and innovative tool whose simplicity and readiness – together with the visual stimuli that it induces – may be profitably used to trace formative pathways for students (and teachers), so as to improve their awareness and involvement in key topics of environmental education. It is noteworthy that, though primarily an educational exercise, the survey introduced a research element and the regional picture of air pollution that emerged has increased our knowledge of the present air quality situation in coastal Tuscany.

Apart from the educational aspects stressed above, the monitoring of environmental health with living organisms should be regarded as a highly politically correct issue. The 'Chart of European cities for a sustainable development' (Aalborg, DK, May 27, 1994) emphasises the setting of mechanisms able to improve the awareness of problems and implies the active participation of citizens in the assessment of several indicators of the state of the environment. Under this point of view, biomonitoring of aerodispersed pollutants may represent a key element and a new discipline, 'environmental horticulture', may be envisaged (Burchett, 1995). With these methodologies, air quality information can be provided to the public in a format that is understandable and relevant to their needs ('receiver-friendly'). The practical implications in landscape and urban planning could be quite interesting (Posthumus, 1982), considering the several strategic options available for planners to control vehicle-related air pollution (e.g., traffic management especially at hot spots (speed limits, lorry rerouting, flow optimization, reducing vehicles mileage, incentives for cleaner vehicles, road pricing), apart from developing alternative transport modes. As the degree of environmental concern has a strong impact on our behaviour in specific environmental related domains such as mobility (Bamberg, 2003), developing in young people a precise scenario on the overall impact of present way of life may be strategic.

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References

ANPA (Italian Agency for Environmental Protection, Rome) (1999). In C. Piccini & S. Salvati (Eds.), *Biomonitoraggio della qualità dell'aria sul territorio nazionale*. Rome: Agenzia Nazionale per la Protezione dell'Ambiente.

Bamberg, S. (2003). How does environmental concern influence specific environmentally related behaviors? A new answer to an old question. *Journal of Environmental Psychology, 23*, 21–32.

Beaumont, R., Hamilton, R. S., Machin, N., Perks, J., & Williams, I. D. (1999). Social awareness of air quality information. *Science of the Total Environment, 235*, 319–329.

Brimblecombe, P., (2003). *The effects of air pollution on the built environment*. London: Imperial College Press.

Brimblecombe, P. & Maynard, R. L. (2001). *The urban atmosphere and its effects*. London: Imperial College Press.

Burchett, M. D. (1995). Horticultural aspects of environmental issues in urbanized society: The gardens as a model for caring the earth. *Acta Horticulturae, 391*, 77–88.

Castell, J.-F., & Maronnier, D. (2002). Biomonitoring of ozone: A tool to initiate the young people into the scientific method and air pollution impacts. In A. Klumpp, A. Fomin, G.

Klumpp, & W. Ansel (Eds), *Bioindication and air quality in European cities* (pp. 265–269). Stuttgard: Heimach.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement, 20*, 37–46.

Colbeck, I., & MacKenzie, A. R. (1994). *Air pollution by photochemical oxidants*. London: Elsevier.

Emberson, L., Ashmore, M., & Murray, F. (2003). *Air pollution impacts on crops and forests*. London: Imperial College Press.

Heggestad, H. E. (1991). Origin of Bel-W3, Bel-B tobacco varieties and their use as indicator of ozone. *Acta Horticulturae, 74*, 264–291.

Landis, J. R., & Koch G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*, 159–174.

Lorenzini, G. (1994). A miniaturized kit for ozone biomonitoring. *Applied Biochemistry and Biotechnology, 48*, 1–4.

Lorenzini, G., & Nali, C. (2004). Bio-monitoring of ozone by young students. *Journal of Biological Education, 38*, 158–162.

Lorenzini, G., Nali, C., Dota, M. R., & Martorana, F. (2000). Visual assessment of foliar injury induced by ozone on indicator tobacco plants: A data quality evaluation. *Environmental Monitoring and Assessment, 62*, 175–191.

Nali, C., Catoni, C., & Lorenzini, G. (2006). A case study of environmental education: Biomonitoring of ozone with young students. *Proceedings of 3rd World Environmental Education Congress, Torino, Italy, 2–6 October 2005*.

Nali, C., Ferretti, M., Pellegrini, M., & Lorenzini, G. (2001). Monitoring and biomonitoring of surface ozone in Florence, Italy. *Environmental Monitoring and Assessment, 69*, 159–174.

Nali, C., Pucciariello, C., & Lorenzini, G. (2002a). Mapping ozone critical levels for vegetation in Central Italy. *Environmental Monitoring and Assessment, 141*, 337–347.

Nali, C., Pucciariello, C., & Lorenzini, G. (2002b). Ozone distribution in central Italy and its effect on crop productivity. *Agriculture, Ecosystems & Environment, 90*, 277–289.

Olea, R. A. (1974). Optimal contour mapping techniques using universal kriging. *Agriculture, Ecosystems & Environment, 79*, 695–702.

Posthumus, A. C. (1982). Biological indicators of air pollution. In M. H. Unsworth & d. P. Ormrod (Eds), *Effects of gaseous air pollution in agriculture and horticulture* (pp. 27–42). London: Butterworths.

Saitanis, C. J. (2003). Background ozone monitoring and phytodetection in the greater rural area of Corinth-Greece. *Chemosphere, 51*, 913–923.

Saitanis, C. J., & Karandinos, M. G. (2001). Instrumental recording and biomonitoring of ambient ozone in Greek countryside. *Chemosphere, 44*, 813–821.

Saitanis, C. J., Katsaras, D. H., Riga-Karandinos, A. N., Lekkas, D. B., & Arapis, G. (2004). Evaluation of ozone phytotoxicity in the greater area of a typical Mediterranean small city (Volos) and in the nearby forest (Pelion Mt.)-Central Greece. *Bulletin of Environmental Contamination and Toxicology, 72*, 1268–1277.

Toncelli, M. L., & Lorenzini, G. (1999). Comparative evaluation of biomonitoring techniques of tropospheric ozone. *Environmental Monitoring and Assessment, 55*, 445–458.

Tonneijck, A. E. G., & Posthumus, A. C. (1987). Use of indicator plants for biological monitoring of effects of air pollution: The Dutch approach. *VDI-Berichte, 609*, 205–216.

WHO (World Health Organization) (1999). *Health costs due to road traffic-related air pollution*. Copenhagen: WHO.