Air ions: measures 1998-2019

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Abstract. In the context of the general assessment of electromagnetic pollution present in a given area, campaigns of measurements of the atmospheric electrical parameters were carried out for a long time with an air ions meter we have designed and realized through a not easy path: the “Ionmeter”. Each of these campaigns was originated by requests of Municipality or School or Clinics, and we caught these commitments also like an occasion for tuning, calibrating and testing the AIM-101 “Ionmeter”. The main characteristic of this device is to enjoy an advanced electronics design, such that enables it to perform measures with a very high power of resolution (HPR). The latter is necessary to study at a finer level of the air ions two fundamental parameters - concentration and mobility - as, e.g., it is demanded when one wants to quantify the correlation between emerging malaises in an indoor situation and the collapse of the small ions concentration; or, outdoor, the role of climate on human health, notoriously linked to the variations of atmospheric “spatial charge”. The collected data and the improvement acquired in the campaigns, we’ll describe in this paper, together with the correlations observed in artificial electromagnetic fields, allow us to present finally the device with the highest power of resolution available today.

1. Introduction

The association between extremely weak “fields”, such as air ions, and the response in terms of human health to the stress they represent, eminently towards the respiratory and cardiovascular system, has been scientifically hypothesized. Air ions have been studied for many decades as an important parameter for determining the microclimate: there is a high correlation between the electrical conductivity of the lower atmosphere and the ionization of the air, and the latter is decisive for the microclimate in which people live [1-5]. If we look at a confined environment like are a laboratory, an office, a classroom, a workshop it might be improper to speak of microclimate, it would be better referring to an indoor situation with a specific air ions characterization.

An association between the concentration of “small ions”, which are generally negative, and a state of good health or a significant positive change in human behavioral parameters has been repeatedly suggested over several decades [6-22]. One of the key arguments supporting this claim is the verified emergence of physiological disturbances when the concentration of small ions is sensibly falling. In any case, if one wishes to testify to that association, it becomes a priority to carry out reliable measurements of the characteristics of the air ions of a given place [17], internal or external, and
collect statistically significant data. A second step is to understand what the threshold, if any, is for the ion concentration of the air below which disturbances arise. Finally, try to give the onset of disturbances a verifiable quantification through measures that, it is easy to predict, would require a very high sensitivity.

In the perspective of the association “small ions/good health” we have conducted several campaigns for satisfying the above underlined priority, that is, to characterize air ions parameters in an environment, indoor as well as outdoor. This article is a review of the campaigns conducted by the authors, eventually aided by some collaborators. The pandemic has stopped the possibility of other campaigns, but in truth we have to say that there has been a strong decline in health and social interest for this kind of investigation: the costs of instruments and their application are too high, the attention health in the workplace has significantly decreased in these thirty years.

Referring only to research profiles, the key aspect to mention is that the accuracy of air ions characterization requires an instrument of high power of resolution (HPR) for measurements [17].

2. The materials and methods

In order to prove the association of which we are talking about, the first step is the reliability of the data obtained from the measurement, that, in turn, depends on instrumental performances.

Starting from the last Eighties we noticed that the instrumental performances exhibited in scientific literature on how many couples of air ions were detectable for unitary volume were completely in contradiction with the electronic layout provided as a proof of the obtained results.

It was not a matter of small systematic errors, even less of aleatory variances, because the difference between the claimed power of resolution and what the designed electronics could provide could be up two order of magnitude. In other words, the twenty couples of air ions declared as the resolving power of the instrument presented in an article were just a claim: in our survey of the different designs we have tested, the difference between what was claimed and what that the electronics scheme could really give was of ten times, in the best case, but up to hundred times in other cases, obviously in worse.

On the other hand, reliable values of the concentrations of small ions both in atmosphere and in confined environments were established with the electromechanical instrumentation then available in the 1960s-1970s [23-25], but, besides the lack of a digital transduction that makes easier to collect, represent and store in archive the data of measure through electronic software, the complex procedures of those measurements were time demanding and, for all these reasons, more subject to errors. Further, it should be noted that since the last Eighties precise measurements of the concentration of small ions have no longer been made.

The creation of an our instrument with a high power of resolution (HPR), an “Ionmeter”, capable of truly detecting even a tens of air ions, that is about 10 fA peak-to-peak current (1 fA = 10^{-15} Ampere), as claimed in several scientific papers, was a difficult path for the scarce support obtained from University research fund and, searching for private aid, the already mentioned strongly declining social interest about the healthcare in worksites. Thus, to fund the creation of “Ionmeter” were important also several individual contributions from technicians involved in the research; and the passage from the prototype to the actual instrument was made possible through taking in charge its creation by MCS, mainly by its CEO, Mauro Santilli.

Anyway, also the prototype proved of being able to maintain the designed performances; therefore, we were able to carry out some reliable measurement campaigns. In the last two years measurements have been carried out with the actual “Ionmeter”. As things stand, we know by online information that the possible “Ionmeter’s” competitors are far from its HPR; and a look into industrial products makes likely that the advanced electronics requested by a HPR instrument have become a matter of military laboratory and manufacturing.

It is reasonable to ask whether the goal deserved all these difficulties. The answer is simple: the onset of disturbances of a good state of health corresponds to the fall of small ions from the several hundred normally inherent in that state to much less. How much less? It is a question of being able to appreciate about ten of them. Without a device capable of such a performance, the link “small
ions/good health”, so credibly hypothesized, risks wandering for other decades without a real proof, that is, a quantification provided by high-sensitivity measurements. The campaigns to measure air ions concentration and mobility resorting to “Ionmeter” have been conducted from the last Nineties up to 2019. Each campaign was born as a request of an Institution or a Municipality to test air ions pollution in sites of their concern.

The “Ionmeter” AIM-101 (Figure 1), thanks to the precise electronic and the mechanical design, allow to measure with accuracy the following quantities:
1. the concentration of the small positive and negative ions (n⁺, n⁻);
2. the conductivity of the air due to small ions;
3. the spectrum of mobility;
4. the size of the ions;
5. the conductivity of the air due to small and intermediate ions;
6. the net space charge density;
7. the local atmospheric electric field at 1 m above the ground.

This “Ionmeter” allows the simultaneous and real-time reading of the concentration of positive and negative ions with a measuring range that extends from 10 to 10⁶ ions/cm³ and, with a measurement error on all scales of ± 10 ions/cm³.

Ions are captured by two coaxial structure cylindrical transducers with gold plated electrodes. Two power supplies with output voltage ranging from zero to 350V provide the right, biasing of the transducers. Inside each transducer, a specific air flux is guaranteed by using a regulated speed fan, enabling the ions on the electrodes to be turned into voltage by two current/voltage converters based on amplifiers with extremely low bias current.

Both converters are enclosed in a controlled temperature box to provide high stability in continuous measurements and through an operating temperature range from -20°C to + 50°C. Analog outputs are digitized and managed by the local microprocessor together with other data, such as transducer electric potential, ambient air temperature and air relative humidity.

All the acquired data are sent by the interface to the computer, where the main program allows data logging, data computing, results displaying and reporting.

The management software of “Ionmeter” is a user-friendly tool that operates in Windows environments. Measurement set-up is easily configurable, and all options are stored within initialization file, and automatically loaded during the program start-up.

Concentration mode plots in real time, on a self-scaling graph, the positive and negative ion densities gathered by the ionmeter through the time. On the screen there are also shown the current
measure parameters, such as Transducer Voltage, Air Speed, together with Air Conductivity and Mobility that are parameters related to ion density. Mobility mode plots as histogram the relationship between ion mobility and concentration. For each preset mobility step, the program adjust the measure parameters and averages the density data through the step time producing the relative histogram bar.

In both modes data can be stored on the computer to be reviewed and analyzed later. The software has also a Calibration function which allows the compensation of repetitive and ambient related measurements errors. Calibration is accomplished energizing the transducer and without air flux, collecting data during a fixed period of time to remove any error source that can affect the measure. All recorded data can be reviewed and printer in graphic form using the standard Windows printer and exported in ASCII (text) format to allow further analysis.

3. Results

3.1. School “Giacomo Leopardi”, Rome

In the Giacomo Leopardi school (Rome, Italy) the concentration and spectrum of air ions were measured in 1998 (Figure 2). The measurements made show that the ionization of the air on which the school is located is that typical of urban environments surrounded by greenery: ionic concentration greater than 100 and less than 500 pairs of ions/cm$^3$. The space charge density is normal ($\sim 10^{-13}$ C/m$^3$); therefore the electrical parameters of the outside air are not altered due to the high values of the artificial radio frequency electric field detected in the area under examination.

![Figure 2. “Giacomo Leopardi” School. Places where the electrical characteristics of the air were measured.](image-url)

The Refectory present the concentrations of air ions typical of confined air environments with little ventilation of the room (Figure 3, Table 1): we note the predominance of positive ions. Unlike in pavilion “J”, where the vastness of the environment ensures sufficient replacement of the intramural air, but the atmospheric electric field is absent, the ionic situation of the air presents a situation in which the $n^+ / n^-$ ratio is lower of one (Figure 4 and Table 2).

| Parameter                      | Unit of Measure | Date: February 18, 2019 |
|--------------------------------|-----------------|-------------------------|
| Average concentration of small ions | Ions/cm$^3$ | 401.41 | 148.10 | 2.71 |
| Conductivity of the air | 1/Ω·cm | $\sigma^+$ | $\sigma$ | $\sigma=\sigma^+ + \sigma^-$ |
| Space charge density | C/m$^3$ | $\rho$ | 40.5·10$^{-12}$ |
| Intensity of the electric field | 500 kHz - 3 GHz | V/m | 1.5 | 1.5 | 2.0 | 2.0 |
Table 2. Atmospheric electrical parameters and radiofrequency electric field in pavilion “J”.

| Parameter                          | Unit of Measure   | Parameter                          | Unit of Measure   | Date: February 18, 2019 | Place: Pavillon “J” |
|-----------------------------------|-------------------|-----------------------------------|-------------------|--------------------------|---------------------|
| Average concentration of small ions | Ions/cm³          | n⁺                                | 65.16             |                         | Pavillion “J”       |
| Conductivity of the air           | 1/Ω·cm            | σ⁺                                | 1.61·10⁻¹⁷        |                          |                     |
| Space charge density              | C/m³              | σ⁻                                | 1.49·10⁻¹⁷        |                          |                     |
|                                   |                   | σ=σ⁺+σ⁻                          | 3.10·10⁻¹⁷        |                          |                     |
|                                   |                   | ρ                                 | ~1.00·10⁻¹²        |                          |                     |
| Intensity of the electric field   | 500 kHz - 3 GHz   | 1m from the ground Max value      | 2.0               |                          |                     |
|                                   |                   | 1m from the ground Average value  | 2.0               |                          |                     |
|                                   |                   | 2m from the ground Valore max     | 3.0               |                          |                     |
|                                   |                   | 2m from the ground Average value  | 3.0               |                          |                     |
3.2. Guadagnolo and Genazzano (Rome)
The mapping of the electromagnetic environment of the municipal territory of Genazzano started in 2000. Logistic troubles and difficulties met during measurements yielded, at the end, not reliable results. A new mapping of Genazzano, now with another municipality close to it, Guadagnolo, was taken again in 2005-06 with satisfying results.

The mappings for these two small cities, in the province of Rome, highlighted a notable difference between them. Genazzano was a country, rare in Italy, in which electromagnetic pollution was almost absent, while Guadagnolo presented, within the inhabited center, a high value of artificial electromagnetic fields in the region of the high frequency spectrum. The temporal trend of the concentration of air ions in the area where the municipality of Genazzano is located can be considered as typical of non-urban environments in good weather conditions, characteristic of healthy microclimates (Figure 5). In the graph it is possible to observe the lack of abrupt fluctuations in the ionic concentration and the predominance of negative ions (average ~ 200 ions/cm$^3$) compared to positive ions (average ~ 150 ions/cm$^3$).

![Figure 5. Average concentration of small ions - June 23, 2006 (negative ions in blue and positive ions in red). Genazzano, Italy.](image)

A series of “spot” measures realized 2012-2013, in the same areas of Genazzano where the previous mapping was made, gave very closer results to those represented in Figure 9; therefore, those areas, if not meanwhile altered, can be a good test not only for measurements with the “Ionmeter”, but also, more generally, to produce a spectrum of natural electromagnetic fields in a very large band of frequencies.

3.3. Climate and health Conference, Rome
The Conference on Climate and Health was held on Tuesday 21 April 2015 at the Aviator’s House in Rome. The Conference was organized by Dr. Vincenzo Valenzi of the Center for Biometeorology Studies. During the conference the concentration of the small air ions was measured with the “Ionmeter” (Figure 6, Table 3). This synthetic measure of the concentration of small ions confirms previous observations, which indicate a decrease in the number of negative ions in confined air environments when many people are present.

![Figure 6. “Ionmeter” for detecting concentration of small ions.](image)
Table 3. Average concentration of small ions –“Casa dell’Aviatore”.

| Parameter                        | Place: Aviator’s House | Time | Date: April 21, 2015 |
|----------------------------------|------------------------|------|----------------------|
| Average concentration of small ions |                        | hour | n⁺ Ions/cm³ | n⁻ Ions/cm³ | n⁺/n⁻ |
| Start of measurement             |                        | 0    | 85.30       | 92.16       | 0.93   |
| End of measurement               |                        | 2    | 82.13       | 75.40       | 1.09   |

3.4. Municipality of Casalecchio di Reno

In the electromagnetic environmental monitoring of the municipality of Casalecchio di Reno, Italy (2018 - 2019), the electrical parameters of the air were measured in some areas of the city. We chose the same places where the electrical characteristics of the air ions had been measured in a previous campaign (1997-1998) in order to test a possible difference between the values of the measurements obtained from the prototype and those of the present device. The repetition of the test in that territory had good reasons: a larger set of places dedicated to different uses than in other our campaigns; the historical issue that the previous campaign had taken place, at the request of the Municipality, in the context of “Healthy Cities”, a project launched by the WHO; the warm hospitality received, also a pleasant replica of the first campaign.

The operational activity was significantly faster than in the past, mainly thanks to the improvement of the software of the “industrial” version of the “Ionmeter”, as developed by MCS. The values of the measurements differed from those of the previous campaign by a maximum of a few units as regards the small negative ions, which is an expected and satisfactory result, the small difference being attributable to the impossibility of replicating the same environmental conditions (Eraclitus docet).

The list of places: Biblioteca Comunale (Municipal Library), Supermercato “Coop” (Coop Supermarket), Clinica “Villa Chiara” (“Villa Chiara” Clinic), and Scuola “Vignoni” (School).

In Figures 7-10 you can see the concentration and the ionic spectrum of the 4 examined sites. In the municipality of Casalecchio di Reno, the quality of the air is decidedly unhealthy from an electrical point of view. The spectrum of air ions highlights the preponderant presence of intermediate (mobility <0.76 cm²/V·s) and large ions (mobility <0.33 cm²/V·s) of both signs. This phenomenon highlights the presence of chemical pollutants. In the “Villa Chiara” Clinic, in the operating room, complete deionization of the air is recorded! This is probably due to the presence of air conditioning devices. The Municipal Library and the Coop Supermarket have ionic concentrations typical of confined and poorly ventilated environments. In the school the situation is similar to that of the Leopardi school in Rome.

Figure 7. Average concentration of small ions. Due to the low ion concentration, the spectrum is not representable. “Villa Chiara” Clinic (Casalecchio di Reno).
Figure 8. Average concentration of small ions and their spectrum. Municipal Library (Casalecchio di Reno).

Figure 9. Average concentration of small ions and Spectrum of air ions. Coop Supermarket. (Casalecchio di Reno).

Figure 10. Average concentration of small ions and their spectrum. “Vignoni” Nursery School (Casalecchio di Reno).
4. Conclusions
It is necessary to perform measurements with innovative devices with high power of resolution (HPR) to ensure a methodologically safer basis for models and interpretative theories of the interaction between air ions and biological systems, or for finally assessing the well-founded hypothesis of health effects by air ions in correspondence to variations of their fundamental parameters (concentration, mobility). The “Ionmeter” is the only device on market able to measure concentration, conductivity and spectrum of atmospheric air ions up to the level of 10 fA (fentonAmpere = 10^{-15} Ampere). The need of such a sensitivity has been explained. The software of “Ionmeter” has been updated so that the graphical representation of the measurements can be adequate at that level of accuracy. Finally, the circle can be closed because now another HPR device of advanced electronics, APEC 300, has become available also to quantify the health response to different values of air ions parameters in terms of corresponding variations of electro-cutaneous parameters.

5. References
[1] Marinelli F, Sperin M, Scalia M and Murri A 1991 The air ionization: a new environmental parameter In International Symposium: Water, Atmosphere and Soil, a New Environmental Deal 22-3
[2] Scalia M, Marinelli F and Sperini M 1992 Fenomeni elettrici atmosferici: misure effettuate con il captatore ionico Università di Roma - La Sapienza. Math. Dept.Report 1-7
[3] Marinelli F, Scalia M, Sperini M, Valenzi V I and et al. 1999 Fenomeni elettrici in climatologia: osservazioni in fisiopatologia cellulare mediante strumenti di ultima generazione In 57° Congresso Nazionale Associazione Medica Italiana di Idrologia, Talassologia e Terapia Fisica 99-101
[4] Bhattacharya A B 2011 On Some Characteristic of Tropical Atmospheric and Cosmic Radio Noise International Journal of Engineering Science and Technology 3 (7) 5475-86
[5] Skromulis A and Noviks G 2012 Atmospheric Light Air Ion Concentrations and Related Meteorological Factors in Rezekne Latvia City Journal of Environmental Biology 33 455-62
[6] Gilbert G O 1973 Effect of Negative Air Ions upon Emotionality and Brain Serotonin Levels in Isolated Rats International Journal of Biometeorology 17(3) 267-75
[7] Gualtierotti R 1975 Azioni biologiche della ionizzazione dell’aria. Rassegna della letteratura Lacustrine Environment. Methods of Study 246-78
[8] Lambert J F, Olivereau J M and Truong-Ngoc A 1981 Influence of Artificial Air Ionization on the Electroencephalogram of the Awake Rat International Journal of Biometeorology 25 (1) 71-5
[9] Fornof K T, and Gilbert G O 1988 Stress and Physiological, Behavioral and Performance Patterns of Children under Varied Air Ion Levels International Journal of Biometeorology 32 260-70
[10] Stoupel E 1995 Relationship between Suicide and Myocardial Infarction with regard to Changing Physical Environmental Conditions International Journal of Biometeorology 38 199-203
[11] Kinne S M 1997 A Public Health Approach to Evaluating the Significance of Air Ions (Master of Public Health thesis, University of Texas, Health Science Center at Houston School of Public Health)
[12] Marinelli F, Scalia M, Sperini M Valenzi V I and et al. 1999 The air ionization and the human physiopathology.Preliminary observations with up to date technology In Atti del 3° Congresso di Biometeorologia 71-4
[13] Valenzi V I, Monaco G, Spada S, Messina B and et al. 2003 Ruolo dei SEP (Skin Electric Parameters) nello studio delle meteoropatie Proceedings Congresso SIMI Vincitore Premio CECIL in Annali di Medicina Interna 18 164 e segg.
[14] Avino P, De Lisio V, Grassi M, Messina B, Valenzi V I and et al. 2004 Influence of air pollution on chronic obstructive respiratory disease: comparison between city of Rome and hill-country environments and climates *Annali di Chimica* 94 629-35

[15] Morabito M, Crisci A, Grifoni D, Orlandini S Cecchi L and et al. 2006 Winter air-mass-based synoptic climatological approach and hospital admissions for myocardial infarction in Florence, Italy *Environ Res. Sep.* 102(1) 52-60

[16] Scalia M, Sperini M, Marinelli F and Valenzi V I 2013 *Ioni aerei e salute umana* (Roma: Andromeda, Reprint)

[17] Scalia M, Sperini M and Guidi F 2014 *Effetti biologici degli ioni aerei misure e modelli* (Roma: Andromeda, Reprint)

[18] Wiszniewski A, Suchanowski A and Wielgomas B 2014 Effects of Air-Ions on Human Circulatory Indicators *Pol. Journal Environmental Study* 23(2) 521-31

[19] Scalia M, Sperini M, Valeri G A N and Valenzi V I 2015 Air Ionization and Its Effects on the Health—An Outline of a Research Project *J. of Earth Science and Engineering* 5 306-12

[20] Scalia M, Pulcini F and Sperini M 2015 *Elementi di teoria: lo stato di salute* (Roma : Andromeda, Le Chiavi)

[21] Valenzi V I, Russo M V, Pisani A, Sperini M and Scalia M 2018 Considerations about new theory and technologies for improvement of Health and Performance Status in Microgravity *XIII International conference on the applied biophysics, bionics and biocybernetics* (Kiev: Politechnic Institute)

[22] Valenzi V I, Berevzosky V, Pisani A, Marashi P, Avino M V, Russo M, Sperini M and Scalia M 2019 Climate and Health Safety: between meteoropaties, multiple chemical sensitivity and climatotherapy (V International Scientific Practical Conference) *Technogenic and environmental safety SAFETY-2019* (Saratov)

[23] Israël H 1951 Instruments and Methods for the Measurement of Atmospheric Electricity In: *Compendium of Meteorology* ed T F Malone p 155-81

[24] Chalmers J A and Smiddy M 1960 Measurement of Space Charge in the lower Atmosphere *J. R. Met. Soc.* 86 79-84

[25] Dolezalek H 1973 Remarks on Atmospheric Electricity Measuring Techniques *Pure and Applied Geophysics* (Israël: Memorial Issue)