RESEARCH REPORT ON THE PHYSIOLOGICAL EFFECTS OF AIR IONS AND THEIR SIGNIFICANCE AS ENVIRONMENTAL FACTORS

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16. Abstract

The series of experiments performed have shown that small air ions generated artificially using radioactive materials produce physiological effects in all test subjects, which are described in this report.

These results show that the air ions must be considered as important climatic factors in the production of comfortable and healthy room climates.

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Year	Researcher	Reference	Methodology and Results
1930	Tschijewski	24	Treated lung patients with ionized air and got good curative effects. In rats, under the effect of negative ions, there appeared an increase in movement and sexual activity.
1931	Dessauer	4	Pure unipolar air was generated for the first time. The artificial ionization was 1,000 to 10,000 times stronger than natural ionization. Negative ions showed favorable effects with high blood pressure, rheumatism, headaches, general fatigue; ability to concentrate was increased; states of excitement diminished.
1933	Raiewsky	21	Published review on the entire field of artificial ionization for biological purposes. Negative ions show favorable and clearly curative effects in hypertonics, sinus problems, asthma, migraine, fatigue conditions, and others.
1935	Edström	24	Inhalation of negatively charged air causes reduction of the blood pressure. With positively charged air there is a feeling of warmth and the skin temperature rises due to the change in blood circulation in the skin.

1936	Schmid	24	Most comprehensive publication on the results of the biological actions of air electricity, with consideration of artificial ionization over the last 200 years.
1941	Küster and Barthel	16	Electro-aerosol therapy using the Barthel-Küster ball nozzle. Treatment of asthma, bronchitis, heart and circulatory disturbances, rheumatism, migraine.
1952	Schulz	25	Sudden jumps in the electricity of the open air cause, on certain days, a considerable increase in accident figures as well as a rise in asthma cases, heart problems, rheumatic pains, and others.
1955	Bisa	2	Therapy with electro-aerosols by means of volume inhalation. Different reactions of the patients to positive and negative ions depend on the initial vegetative state of the persons. Demonstrates effect of the electro-aerosols on the autonomic system using the flicker fusion frequency.
1955	Kornblueh	12	Treatment of hay fever and bronchial asthma with electro-aerosols. Also found significant ion effect on the brain alpha frequency.
1957	Krueger	14, 15	Treated droplets of bacterial suspensions with negative and positive ions and found that the death rate of the cells in pure air is significantly increased.

			Studies on the activity of the bronchial ciliary epithelium of mice, rabbits and monkeys showed that the activity increased by about 200 beats/minute under the influence of negative ions, while under the influence of positive ions it decreased by 400 beats/minute or stopped completely. The flow of mucus also decreased. Negative ions also produce slowing of the respiratory rate, while positive ions have the opposite effect. Krueger explains the action as being due to the fact that the negative ions, which were identified as being negatively charged oxygen, act on several intracellular respiratory enzymes.
1961	Minch	18, 19	Athletic students were treated with artificially generated negative ions. Their physical capabilities increased considerably. The metabolism of the vitamins B_1, B_2, niacin, and C, which had been increased in the athletes, became normalized.
1960	Rheinstein	23	Test subjects were treated with artificially produced ions of both polarities and the simple reaction time and the optical moment were measured. The reaction time was lengthened or shortened by an average of 7%, and the polarity of the ions had no effect. The optical moment was not affected.

1962	Eichmeier	5 to 8	Test subjects were treated with small, artificially generated atmospheric ions, and showed statistically significant changes in the respiratory rate (12%), the alpha frequency (2%) and the pulse rate (4%).
1962	Wehner	27	Treatment of asthmatics, bronchitics, and emphysematics with electro-aerosols. Improvement of breathing, sleep, and general feeling, as well as an increase in vital capacity.
1965	Bachmann	1	Rats were treated with positive and negative ions. Both types of ions gave stimulation of the heart rate and respiratory rate.
1968	Varga	26	Test subjects were treated with negative and positive ions. With both types of ions there was a decrease in the heart rate; i. e., a 'calming effect'.

III. Survey of the physics of air ions.

In nature, the same amounts of positive and negative electricity exist — atoms and molecules in the neutral state have the same amounts of positive and negative electricity. This equilibrium can be distorted either by splitting off or by adding on one or more elemental charges. Atoms and molecules which have lost their electrical neutrality in this way are called ions. Small and large ions (clusters) form from the accumulation of air molecules. These not only play a part in the electrical processes in the atmosphere, but are also one of the most important climatic factors in our environment.

Energy must be applied to bring material into the ionized state. This is the so-called ionization energy.

1) Factors which ionize the air

Air ions can arise naturally in the open atmosphere and in closed rooms. But they can also be generated artificially.

a) Natural occurrence in the open air

- due to radioactive materials in the atmosphere
- due to radioactive radiation from the ground
- due to the ultraviolet radiation from the sun
- due to cosmic radiation
- due to gas discharges in the atmosphere, from frictional electricity (lightning).

b) Natural occurrence in closed rooms

- due to cosmic radiation, which penetrates even into living quarters
- due to radioactive radiations from our environment: ground, objects, building stones
- from silent gas discharges caused by frictional electricity
- from glowing bodies for illumination and heating
- from open flames, etc.

c) Artificial occurrence

For practical purposes, air ions are produced in two ways:

- by corona discharges from a spherical, ring, or pointed electrode or a thin wire, to which a high voltage is applied, into the air.

This type of ion generation is not selective. That is, it produces ozone along with the normal air ions. Ozone gives an odor and is toxic over a certain concentration.

- by radioactive particles. At normal pressure, these have a range on the order of a few centimeters in air. In tissue, they have a range on the order of a few micrometers. Radioactive materials of low energy, such as tritium ($H^3\beta$), polonium ($Po^{210}\alpha$), and krypton ($Kr^{85}\ \beta,\gamma$) serve as sources. A radioactivity of 45 - 50 mC is necessary to produce an ionic density in air of about 10^6 to 10^7 ions/cm^3.

This type of ion generator has proved good. One can produce unipolar or bipolar ions with it. The radiations are not a danger for humans because they are rapidly stopped in the air.

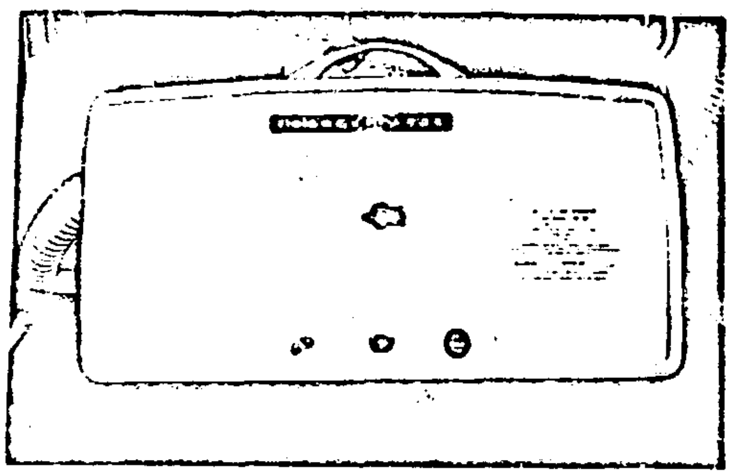


Figure 1. Ion generator with radioactive ionization.

2) Structure of the air ions

The air ions produced with different types of ionization are formed in two ways:

a. Either a neutral molecule is struck by a high-energy particle and split into a positive and a negative part, or

b. An electron or a charged particle deposits on a neutral molecule.

The following monomolecular ions and their combinations can be identified in ionized air with a mass spectrometer [13]:

Positive ions	Negative ions
O^+, O_2^+, O_3^+	O^-, O_2^{--}
N^+, N_2^+, N_3^+, N_4^+	
NO^+, N_2O^+	NO_2^-, NO_3^-
H_2O^+	OH^-
Ar^+	

The ions were determined shortly after ionization, because the picture changes later as the ions recombine, enter into chemical combinations, or form molecular droplets and thus lose their charges.

For this reason, the calculation of the ion concentration in the air at a certain distance from the ion generator proves to be a difficult problem with strict prerequisites. It is simplest, therefore, to measure the ion concentration at a particular location.

3) Measurement of the air ions

The measurement of air ions does not appear very complex in principle; but one must consider some problems in the technological view. The measurements are easiest using a cylindrical capacitor, with which the electrical current due to impacts of the electrical charges on the metal electrodes is tapped off, amplified, and recorded. The principle of the circuit can be seen in Figure 2.

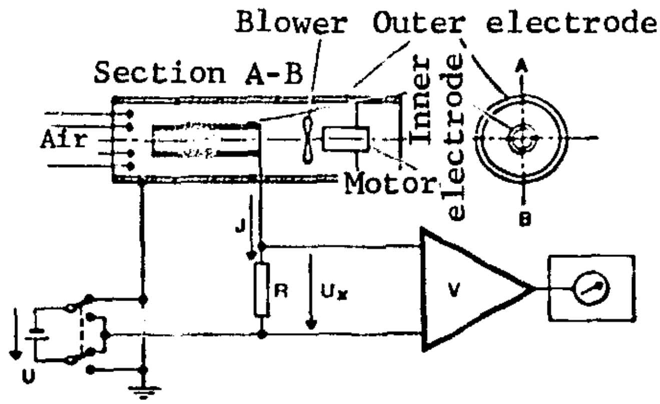


Figure 2. Principle of the ionometer circuit with a cylindrical capacitor as the measuring head.

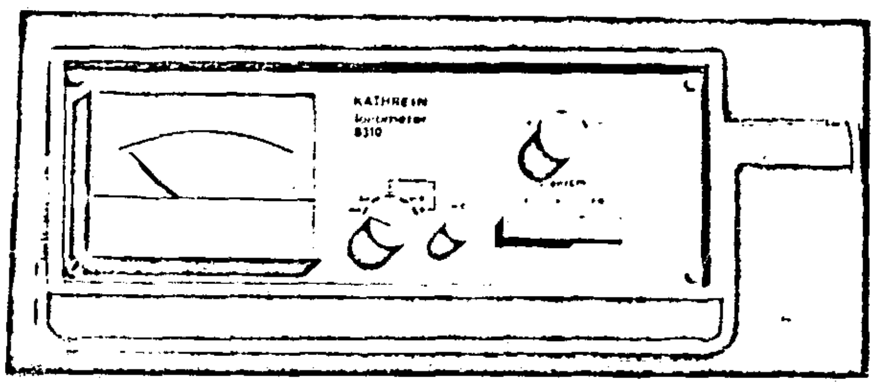


Figure 3. Ionometer with a cylindrical capacitor as the measuring head.

The procedure of measurement is as follows: An electically driven blower sucks the air through the space between the capacitor electrodes. By means of the potential (U) applied to the electrodes, the ions of the corresponding polarity are attracted out of the flowing air, and produce an electrical current. This current, in turn, produces a potential (Ux) at a high resistance. After amplification (V), the potential is read as ion density from an indicator.

IV. Potential physiological action of air ions

1. Principle of the potential effect

The life process is an extremely complex process in which physical and chemical phenomena are closely interwoven, manifesting themselves as the biological process. The latest ecologic information allows the assumption that electrical factors also had an effect in the origin of life. The environmental milieu of the organism shows quite definite electrical properties, and metabolic processes are linked with ion exchange within the body.

For the living organism, changes in these internal and external electrical details mean a change in the life process. It must either adapt to the change, i. e., provide an additional energy expenditure for the adaptation, or, because of the long-term stresses of the distorted internal equilibrium, sicken or even die. Such changes in equilibrium are always linked with energy. The carriers of this energy may be chemical (material, such as ions) or physical (of wave nature, such as fields, radiations). To summarize briefly, one can say:

> A biological stimulus can be exerted if and only if the stimulating energy is converted into electrochemical energy so that the electrokinetic state of the biological boundary surfaces are changed.

This is true both for the micro region and the macro region. An energy density on the order of a few $\mu Ws/cm^2$ is sufficient for this process, as is known from technological information transmission systems. For information transfer between biological systems and their environment, an energy density of only a few pWs/cm^2 may be sufficient.

In our case, the treatment of humans with air ions, the energy carriers are the gas ions from the air, which are neutralized in the respiratory tract as a result of chemical reactions. That is, they either lose their charge or take up a countercharge, so that a stimulating effect is exerted.

2. Ions as climatic factors

The ion concentration in the atmosphere does not depend only on the weather situation, but also on the location, time of day, and season. The ion density varies between a few hundred up to a few tens of thousands of ions per cubic centimeter of air. The polarity is usually positive, but can also be negative. For instance, the biologically active small and medium-sized ions are normally more frequent during the day and with good visibility, while they are less frequent at night and on hazy days. As an example, an increased ion density can be observed after rain or snow, and especially after showers and thunderstorms.

Air ions are also present in living spaces. Their density depends on many factors, but primarily on the electrical properties of the surrounding surfaces, such as the floor, walls, ceilings, openings, the objects in the room, the type of heating, and the air movement in the room. In order to clarify the order of magnitude of the ion density, we take our office as an example. It has dimensions of 5 x 5 x 3.2 meters. It is furnished with plastic flooring having a negative charge which produces a field strength of 20 V/cm in the immediate vicinity of the surface; a window 1.7 x 3 meters, and two doors 2.2 x 1 meter. The furniture includes two varnished tables, two book shelves, also varnished, a writing desk, a chair, and a large central heating register. On 8 November 1971, with damp autumn weather, covered skies, and an outside air temperature of +10°C and a relative air humidity of 57%, the ion density with a gamma count rate averaging

$1.34/min/cm^2$ was:

in the open air: 780 positive ions/cm^3; 310 negative ions/cm^3

in the room: 410 positive ions/cm^3; 690 negative ions/cm^3

The measurements show that ions are always present to more or less extent in our breathing air.

The air ions may be classified into three ion groups on the basis of their physical properties:

	SMALL IONS	MEDIUM-SIZED IONS	LARGE IONS
radius r (cm)	$6 \cdot 10^{-8}$	$(1 - 5) \cdot 10^{-7}$	$10^{-6} - 10^{-5}$
elemental charges (q)	± 1	0 or ± 1	0 to ± 10
mobility, k (cm^2/Vs)	1.5	$10^{-1} - 10^{-2}$	$10^{-2} - 10^{-4}$
lifetime, t	30-300 sec	minutes-hours	days-weeks
concentration, per cm^3	100 - 1,000	$(1\text{-}10) \cdot 10^3$	$(1\text{-}100) \cdot 10^3$

(according to Mühleisen)

Gas analyses in the lungs have shown that the medium-sized ions are the most biologically active. These ions are distributed as follows in the respiratory tract:

retained in the lungs	mouth, throat, larynx	exhaled, about
30%	45%	25%

Detailed investigations [21] have shown that:

a. Penetration into the depths of the lungs is proportional to the weight of the ions (lower mobility) and the depth of respiration.
b. The charge brought into the lungs is collected to a greater extent the lighter the ions are (higher mobility); that is, the larger the number of contacts with the tissue, the longer the respiratory air is retained in the lungs.

3. Physiological data on the human oxygen consumption

The atmospheric air, the oxygen content of which is essential for our life, is made up of the following components [20]:

Nitrogen	ca.	78%
Oxygen	"	21%
Noble and other gases	"	1%

The human air consumption can be calculated from the number of inspirations per minute, which are [20]:

for men	16	inspirations/minute		
for women	18 - 22	"	"	"
for children (10 years)	20 - 25	"	"	"
for children (1 year)	44	"	"	"

If we take a man for example, then we have
16 inspirations/minute with 0.5 liter per inspiration
a respiratory minute volume of 8 liters/minute, or
480 liters/hour or 12 m^3 per day.

The individual organs have the following percentage participation in the oxygen consumption of the body [22]:

abdominal viscera	35%
brain	19%
musculature	18%
heart	10%
kidneys	6%
other organs	12%

It is enlightening that in bodily oxygen deficiency the functions of the individual organs can no longer be carried out optimally.

4. Some research results on the action of air ions

In the course of the last 200 years, air ions have often been used in therapy by physicians, especially for diseases of the respiratory tract. Many results appear doubtful because of their nonreproducibility; but some more recent reports deserve attention; for instance:

a. Investigations by Prof. Strasburger, Dr. Happel and Lecturer Lampert on treatment with negative ions.

Improvement in cases of:
- high blood pressure
- sinus complaints
- asthma
- migraine
- fatigue states

Persons sensitive to weather and climate show the best reactions to this treatment.

b. Investigations by Dr. Schulz.
Treatment with negative aerosols.

Improvement in cases of:
- asthma
- bronchitis
- heart and circulatory disturbances

rheumatic diseases
migraine
whooping cough

c. Investigations by Dr. Ing. Eichmeier
Treatment with atmospheric small ions of both polarities.

Result:	change in respiratory rate	12%
	change in the alpha rate	2.2%
	change in the pulse rate	4.4%

d. Investigations by Prof. Kornblueh
Treatment with electro-aerosols

Improvement in cases of: hay fever
bronchial asthma

Effect on the alpha frequency of the brain.

e. Investigations by Dr. Ing. Rheinstein
Treatment with artificial atmospheric ions of both polarities.

Result: Shortening of the reaction time.
Polarity plays no part.

f. Investigations by Dipl.-Ing. Varga
Treatment with positive and negative ions

Result: Reduction in the heart rate by 3.6% for positive ions and by 3% for negative ions; i. e., a calming effect.

V. Experimental Conditions

1. Climatic conditions

In order to eliminate undesired irritant factors from the environment, to the extent possible, and to hold others at a constant value, the physiological studies were done in a portable climatic chamber. The chamber is double-walled and is made of galvanized steel plate (Faraday cage). It is provided with a set of adjustable climatic variables, which were set to the following values during the entire series of experiments:

fresh air intake	20 m^3/hr
room temperature	22°C
relative humidity	55%
noise level	45 phon
light intensity	350 Lux (at head level)
ion density	$3 \cdot 10^5$ ions/cm^3 (at the mouth of the subject)

As can be seen from the working diagram (Figure 5), our working point is in the normal range of the metal chamber.

2. Biological conditions.

A total of 30 test subjects, who had no information about the nature of the experiments, were treated. They are distributed according to

a. Age	18-20 years	2 subjects
	20-22 "	3 "
	22-26 "	4 "
	26-30 "	6 "
	30-35 "	6 "
	35-45 "	4 "
	45-55 "	3 "
	55-68 "	2 "

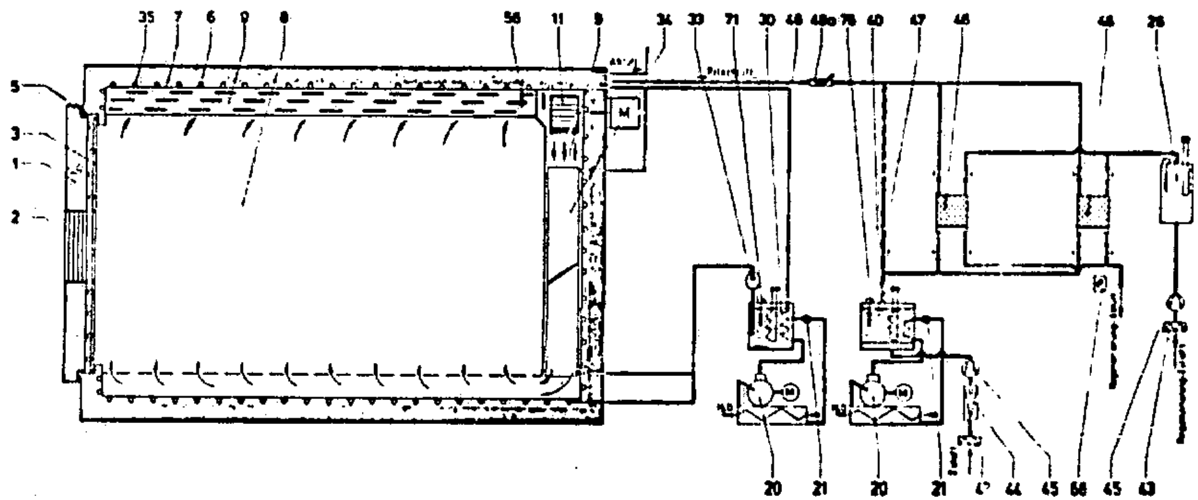


Figure 4. Essential construction of the climate chamber used in the experiments.

1	Outer door	20	Cooling system	40	Humidifier	48a	Addition of noxious gas
2	Viewing window	21	Expansion valve	43	Air filter	56	Exhaust air
3	Test room door	26	Regenerative air heating	44	Air flowmeter	68	Temperature controller
5	Outer door seal	30	Brine thermostat	45	Air pump	71	Brine temperature sensor
6	Insulation	33	Brine pump	46	Drier	76	Humidity sensor Humidifier
7	Test room wall	34	Brine heat exchanger	47	Throttle valve		
8	Test room	35	Brine jacket tempering	48	Fresh air heating		
9	Ventilation duct						
11	Ventilation blower						

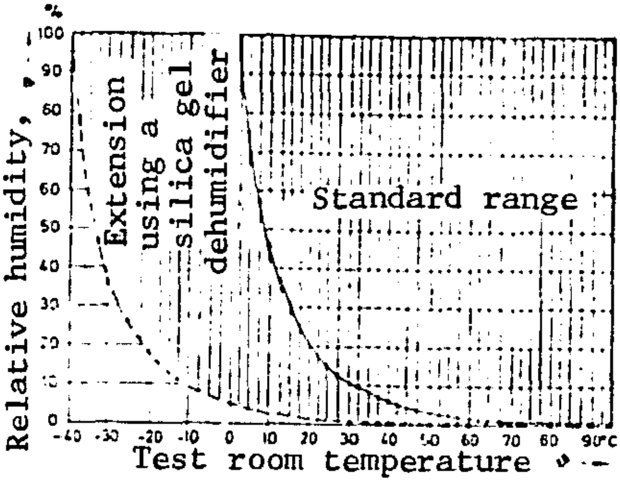


Figure 5. Working range for the climate chamber used in the experiments. Values common for living spaces were selected (T - 22°C and relative humidity = 55%)

b. Sex

	Male	18 subjects
	Female	12 subjects

Both sexes are almost symmetrically represented in all the age classes listed.

c. Occupation

Students	19	subjects
Office workers	3	"
Laboratory employees	4	"
Technicians	2	"
Academics	2	"

d. Physical constitution

All the test subjects were healthy, according to their own statements. Their body weights were between the extremes of 55 kg and 94 kg.

e. Duration of the sitting and methodology.

The duration of one experiment (sitting) was 1 hour. This time was divided into a 20 minute treatment period (P) preceded and followed by 20 minute control periods (K_1, K_2).

The physiological values were recorded every 5 minutes. At the end of each test period, blood was taken for a gas analysis. All the measurement and recording instruments were outside the chamber, and were connected to the test subject by shielded leads. The ion source was 1.10 m from the subject's mouth. The subject sat in a comfortable seat with arm rests and wore a nose clip to ensure that he breathed only through his mouth. There was a suspicion that the different nasal openings might exert a filtering effect, so that they would thus influence the action of the air ions. Later control tests showed, however, that this suspicion was unfounded, as only a very slight difference appeared between nose and mouth breathing.

VI. Effect of air ions on physiological data for humans.

1. Oxygen uptake.

As the table on page 909 shows, oxygen can occur both as a positive and a negative ion. Thus, the ion polarity cannot affect the oxygen uptake.

In this series of tests, it appeared that there are two groups of test subjects:

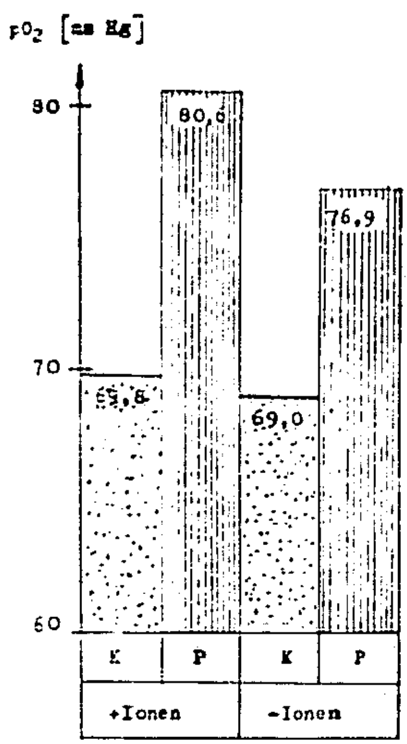
a. those which show increased oxygen content in the blood, and
b. those in which inhalation of air ions showed no changes (smokers).

This difference showed no dependence on age and sex. It proved, however, that without exception, smokers were in Group b, as no change in their blood oxygen content could be detected by gas analysis. The cause of this phenomenon is probably that dilute ions were already present in the tobacco smoke inhaled by the smokers:

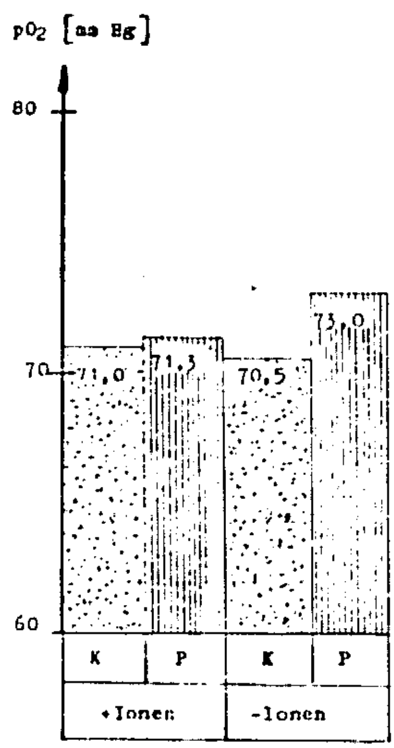
in cigarette smoke:	-	about $2.9 \cdot 10^3$ ions/cm^3
in cigar smoke:	+	" $5.6 \cdot 10^2$ " "
in pipe smoke:	-	" $1.9 \cdot 10^3$ " "

so that the mucous membrane in the respiratory organs has become insensitive due to such continuous irritation.

It did not prove advisable to take averages for the entire number of test subjects, as the results specific for each test subject would be confused in this manner. For clarification, we compare the results from two typical test subjects, one smoker and one non-smoker:



Test subject: M. Ch., non-smoker (average of 30 measurements)



Test subject: H. Sch., smoker (average of 30 measurements

If we average all the results for Group a and for Group b, we get the following values:

Group a	10.7% with + ions 8.2% with - ions	average of 18 subjects
Group b	2.1% with + ions 1.6% with - ions	average of 12 subjects
Groups a and b	6.4% with + ions 4.9% with - ions	average of 30 subjects

On inhalation of + ions the blood has a somewhat higher oxygen content than with - ions; but as the tendency is the same, we may assume that the polarity plays no decisive role.

If one also considers the results which we published in the "Review of Science and Technology", No. 5/1968, page 151, which are reproduced in Figure 6, it is only by means of the present results that it is possible to interpret the result found then. That is that the heart rate decreases on inhalation of air ions. Now it is understandable that less blood need be pumped through the body to provide the same amount of oxygen if the oxygen content of the blood has risen. Therefore, the heart rate must decrease, assuming that the stroke volume remains constant.

Is should yet be noted that, during the oxygen increase under the influence of ionized air, the content of carbon dioxide (CO_2) decreases correspondingly. This is a proof that the gas exchange in the respiratory process in increased. More useful gas (O_2) is taken up and more metabolic product (CO_2) is excreted. The pH value also changes with the O_2 content in about the same manner. That is, the hydrogen ion concentration is somewhat reduced at high oxygen content of the blood, in spite of the great buffer capacity of the blood.

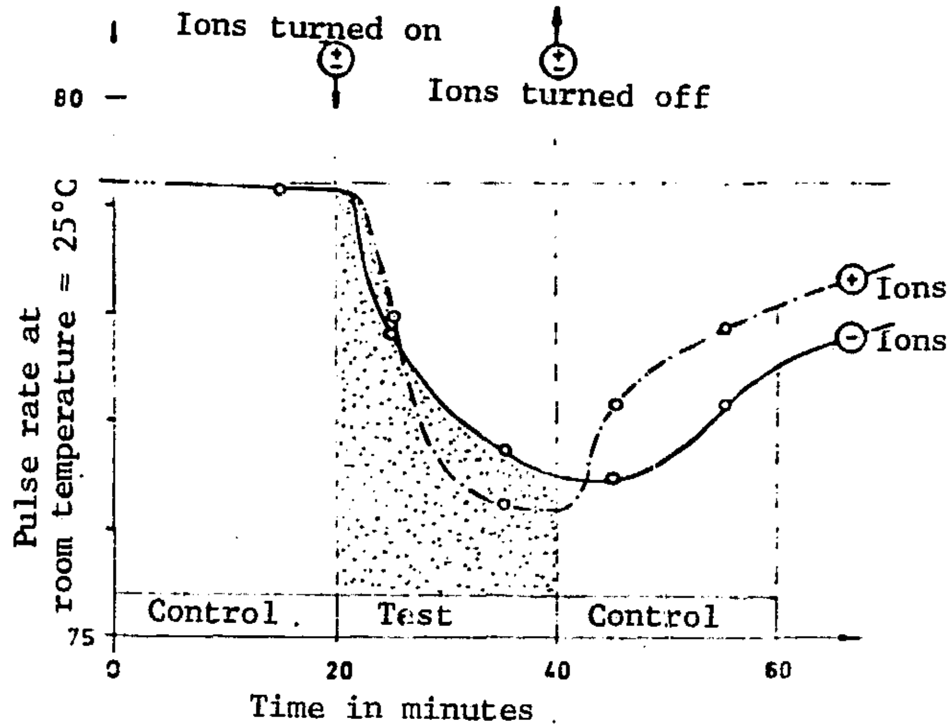


Figure 6. Pulse rate changes in humans under the influence of air ions (average of 24 persons in 177 measurements).

Here is a typical example:

	pCO_2	pO_2	pH
K_1 (20')	35,50 mmHg	71,50 mmHg	7,371
P (20')	30,06 "	81,05 "	7,390
K_2 (20')	34,80 "	77,50 "	7,379

Test subject E. H. under the influence of negative ions.

Practically the same results are obtained on treatment with positive ions.

2. Reaction time for optical signals

A test was made of how a person reacts to an optical signal on inhalation of ionized air, whether the inhaled air ions can affect the human ability for attention and concentration. The reaction time was measured; i. e., the time which passes between the perception of the optical signal and the performance of the muscle motion (pressing a button). Under normal conditions it is between 100 and 300 ms in man.

The reaction time is affected by many factors, such as the time of day, the day of the week, season, weather, the psychic and physical state of the test subject, and many others. Of these factors, we could take into consideration only the time of day and the day of the week, as the others were beyond our power. The experimental system appeared as follows: The operating person, who was outside the chamber, pressed the 'Start' button, starting an electronic clock and simultaneously lighting a red light in the climatic chamber. The test subject was required to extinguish the light as quickly as possible by pressing a button. This also stopped the electronic clock simultaneously. The time which passed is a measure of the reaction time of the test subject.

The results show that three different 'reaction groups' appeared among the test subjects under the influence of air ions:

- with reduced reaction time
- with no change
- with extended reaction time.

Reaction Time	Positive Ions			Negative Ions		
	for	in %	about	for	in %	about
shortened	18 subjects	60	5.8%	15 subjects	50	6.5%
lengthened	8 subjects	26.7	3.4%	11 subjects	36.7	3.7%
no change	4 subjects	13.3	-	4 subjects	13.3	-
Total	30 subjects	100	-	30 subjects	100	-

The percentages shown are group averages for the given number of test subjects, each of whom was tested 30 times.

Typical examples of the reaction times for individual test subjects are presented below:

Test Subject	for positive ions				for negative ions			
	K	P	Δ	Δ%	K	P	Δ	Δ%
V. R.	196	189	-7	-3,6	198	184	-14	-7,1
S. Ch.	203	208	+5	+2,5	210	217	+7	+3,2
G. H.	194	195	1	+0,51	188	188	0	0
K. R.	206	207	1	+0,48	212	220	+8	+3,8

It appears clearly from the table of typical examples that there is no uniform picture. This is probably because of the multitude of factors which play a part here, and which are related to the psychic and physical details for the particular persons. For that reason, it appears advisable to determine first for each person how they react to the inhalation of air ions before deciding on an ionized climate.

3. Changes in pulse rate

The peripheral pulse rate is taken from the finger of the test subject, and the "R peaks" counted electronically. It could clearly be recognized that this physiological value is related to the oxygen content of the blood. A marked reduction in pulse rate could be detected in just those test subjects whose blood showed increased oxygen content, as can be seen in the following table.

Pulse/minute	Positive Ions			Negative Ions		
	for (subjects)	in %	by %	for (subjects)	in %	by %
Reduction	19	63	4.2	17	57	3.5
No effect	11	37	-	13	43	-
Total	30	100	-	30	100	-

These values are averages for the corresponding number of test subjects in the group. For the action of negative ions, only 17 instead of 19 reductions were recorded, as two persons apparently showed no reduction. Two typical examples are shown in the following figure.

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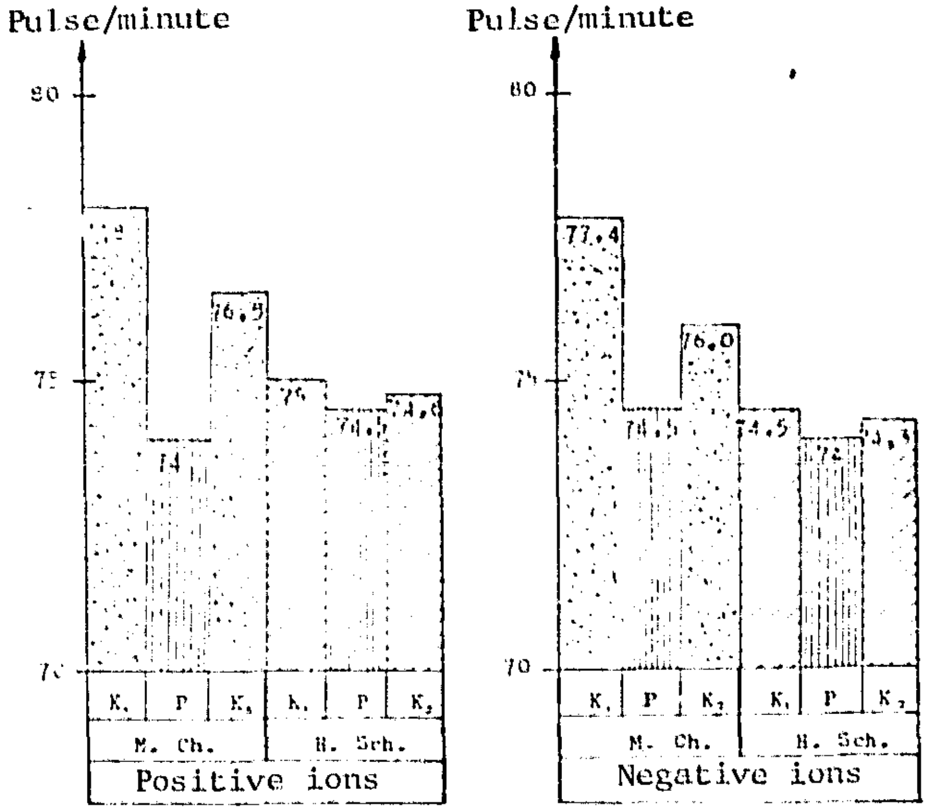

These typical examples show that in no groups does the ion polarity influence the pulse frequency

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4. Blood pressure

The blood pressure was measured electronically without penetration by the Korottkoff noise principle, the noise being detected by a special sound chamber.

Significant changes in blood pressure under the influence of air ions could be observed only with those test subjects which had high blood pressure. The blood pressure measurements under the influence of air ions gave three groups of test subjects:

- distinct reduction of blood pressure — 6 subjects (20%)
- slight reduction of blood pressure — 18 subjects (60%)
- no change in blood pressure (or the values were within the range of variation) — 6 subjects (20%)

A typical example of each group follows:

First Group	K_1 = 150/84 mm Hg	Amplitude 66 mm Hg
Subject E. H.	P = 138/84 mm Hg	Amplitude 54 mm Hg
(22 years)	K_2 = 144/84 mm Hg	Amplitude 60 mm Hg
Second Group	K_1 = 142/90 mm Hg	Amplitude 52 mm Hg
Subject A. W.	P = 138/90 mm Hg	Amplitude 48 mm Hg
(66 years)	K_2 = 140/90 mm Hg	Amplitude 50 mm Hg
Third Group	K_1 = 118/81 mm Hg	Amplitude 37 mm Hg
Subject V. G.	P = 118/82 mm Hg	Amplitude 36 mm Hg
(21 years)	K_2 = 118/81 mm Hg	Amplitude 37 mm Hg

Under the influence of positive ions, one gets the same picture, but with somewhat smaller amplitudes for the particular test subjects.

5. Skin resistance

The galvanic skin resistance represents a measure of the peripheral blood flow. The more blood there is in the skin capillaries, the lower the galvanic skin resistance is.

The galvanic skin resistance is measured with special unpolarized gelatin electrodes and a high-sensitivity measuring bridge. A current of 40 μA flows in the circuit during the measurement. With our electrode surface, this gives a current density of 12.7 $\mu A/cm^2$, which is insignificant from the electrolytic viewpoint.

The following 'segments' were measured:

Hand - Hand ($H_l - H_r$), Foot - Foot ($F_l - F_r$),
Hand - Foot ($H_l - F_l$), ($H_r - F_r$), and
crossed Hand - Foot, ($H_l - F_r$) and ($H_r - F_l$).

in a total of six circuits.

The action of air ions gave the following averages in kOhm for all 30 test subjects:

	H_r-H_l	F_r-F_l	H_r-F_r	H_l-F_l	H_l-F_r	H_r-F_l
K_1 (20")	202.20	229.24	217.96	205.42	220.86	198.88
P (20")	198.31	232.80	217.45	224.81	229.33	186.85
K_2 (20")	203.02	230.08	219.37	206.01	219.91	193.70
Change	increased	increased	none	increased	increased	reduced

Under the action of positive ions, an increase could be measured one time and a reduction another time in one and the same subject. As the range of variation is so great, there is no predictive ability in this case.

VII. Discussion

The importance of these research results is primarily in the fact that they demonstrate that the oxygen content of the blood is increased on inhalation of ionized air. Respiration is of vital importance for humans, but only a percentage of the oxygen is taken up from the inhaled air and the remainder is exhaled again. If the air is ionized, in comparison, we can absorb more oxygen. This represents a gain for the human body, which can be manifested in various ways, as each person is different, and in addition the particular physical and psychic state of the person must be considered.

Air ions are not only static charges. Rather, with their flowing charges they form an electric current which can exert a stimulus in biological media. That is, this energy can excite a reaction in certain persons and in certain sites of the organism. For this reason, the electrical conductivity of the air, the ion density of our environment, is not without significance, so that the increasing pollution of the air must be viewed doubtfully.

The fact that the oxygen content of the blood is raised on inhalation of ionized air justifies our assumption that this is the reason for the decrease in pulse rate, as the body is supplied with the necessary oxygen by less blood. This phenomenon also agrees well with the observed reduction of blood pressure in hypertonics.

The consumption of irritants, such as tobacco, can disturb the normal reaction of the body to oxygen ions so that there is no resulting increased oxygen uptake by the respiratory organs. The body (mucous membrane) is prestimulated, so that the stimulus threshold for the air ions is obscured. The blood gas analyses in this work have shown that smokers without exception show no increase of blood oxygen on inhalation of ionized air.

These research results have provided valuable information for air conditioning technology. Architects should not ignore the air ion content in their plans for dwelling and residence areas and conference and working rooms. Along with the air humidity, they form the basis for a comfortable room climate, one of the prerequisites for human health and well-being.

It should also be mentioned in this connection that the air is usually dry in the centrally heated rooms which are most common today. This leads to an irritation of the mucous membranes which in this manner become particularly sensitive and susceptible to infection. In the winter, body adaptation is made more difficult by the sudden change from overheated rooms to the cold, wet outside air, greatly increasing the susceptibility to colds. For a healthy room atmosphere in dwellings and residences, the relative humidity should, therefore, be at least 40%. The technological capabilities exist today for a better supply of the body with oxygen through the influence of air ions and the provision of optimal room humidity.

VIII. Summary

The series of experiments performed have shown that small air ions generated artificially using radioactive materials produce the following physiological effects in all test subjects, with a few exceptions:

Oxygen partial pressure in the blood increased up to		11%
Pulse rate reduced up to		4.2%
Blood pressure in hypertonics reduced by up to		8%
Reaction time to optical stimulus	reduced by up to	6.5%
or	extended by	3.7%
Skin resistance changes could not be detected in these studies.		

These values are averages from 30 test subjects of various occupations, ages, and sexes. The reactions were almost the same for treatment with positive and negative ions. That means that the polarity plays no part in the physiological range.

These results show that the air ions must be considered as important climatic factors in the production of comfortable and healthy room climates.

IX. Bibliography (translated titles)

2 The electro-aerosols

4 Ten years of research at the physical-medical interface

5 The bioclimatic effect of artificially generated small atmospheric ions on the human respirogram, electrocardiogram and electroencephalogram

6 Properties and biological effects of small atmospheric ions

7 Action of atmospheric ions on biorhythms in humans

8 Mobility spectra of natural atmospheric ions in the small and medium-sized ion region

9 On the biological-therapeutic importance of artificial air ions

10 Natural and artificial ionization and their medical application

13 Physical and biological effects of "small ions" produced in the air

16 Recent results of studies on the action of artificially ionized air on higher organisms.

17 On variations of atmospheric ions and their biological effect

18 Air ionization as a factor in health

21 Air ions and their biological application

22 Human physiology

23 The effect of artificially generated atmospheric ions on the simple reaction time and the optical moment

24 Biological effects of air electricity, with consideration of artificial ionization

25 The significance of air electricity, of electro-aerosol therapy, of direct electrostatic charging therapy according to Takata, and their biological effect on the vegetative nervous system, with consideration of the vegetonogram.

26 Effect of air ions on the heart rate

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