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Atmospheric ions and comfort

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INTRODUCTION

There has been an interest in ionization as related to ventilation since Dessauer and his colleagues (see Dessauer, 1931) published their findings on the effect of ionized air. Opposite effects were claimed for ions of opposite polarity. Negative ions were considered the beneficial ones, evoking a feeling of wellbeing, lowering pulse and metabolic rate. Opposite effects were ascribed to positive ions.

These claims soon were checked in the U.S. by Yaglou, Brandt & Benjamin (1933) and Herrington (1935). Yaglou and his associates concluded that '...nothing definite was found to justify the use of artificial ionization in general ventilation'. On the other hand, Kornblueh (1960) recently stated that the possibility of a correlation between human comfort and the ion content of air cannot be disregarded; he also expressed the hope that a systematic examination of these phenomena will be undertaken.

PRESENT STUDY

The present study was undertaken in order to investigate the influence of atmospheric ions on comfort, oral temperature and pulse rate in apparently healthy people. The subjects were not aware of the purpose of the study and only knew that comfort in general would be tested.

Experimental conditions

Thermal background

Two different air temperatures were chosen to form the thermal background, one (78° F.) evoking a mean thermal vote of near to 'comfortable', the other (87° F.) a mean vote of 'warm', on a seven-point thermal comfort scale. An air temperature of 78° F. was selected as to provide thermally optimal conditions, and a temperature of 87° F. was taken as to exert a slight thermal stress, said to accentuate the action of ions. These temperatures may appear rather high, but the fans built into the ion generators caused a clearly noticeable air movement which exerted a cooling effect. The relative humidity in both instances arbitrarily was kept close to 50%.

Ion generators and counter

Four ion generators were suspended from the four corners of the ceiling. Ions were generated by a controlled electrical corona discharge between a small tungsten wire and grounded electrodes. A direct current (d.c.) potential of several thousand volts was applied to the tungsten wire from a d.c. power source mounted near the ionizer. Positive or negative ions were generated by applying a different polarity to the tungsten wire. A small fan blowing air through the ionizers discharged the ions into the room. The ion counter which was adjusted to register the concentration of ions having a mobility of 0·05 (cm./sec.)/(V./cm.) or greater, was located in the centre of the room which was described in a previous paper (Koch, Jennings & Humphreys, 1960). By reversing the polarity of the collecting and deflecting electrode, positive or negative ions could be counted.

Dummy switches on the ionizers which were pressed, rendered the true switching operations inconspicuous.

Generators and counter were kindly given on loan by Philco Corporation.

Ion levels

Three different levels of ionization were used:

(1) Ordinary air, called 'background' ionization. For this condition the ion content of the air was not intentionally changed, though some change might have been brought about in the process of air-conditioning. Ion counts were up to 500 positive and up to 250 negative ions per ml.

(2) Air enriched with positive ions, called 'positive' ionization. Average ion count per ml. at 78° F. was 12,324, and at 87° F. 14,865.

(3) Air enriched with negative ions, called 'negative' ionization. Average ion count per ml. at 78° F. was 5,451, and at 87° F. 5,442.

Comparing the two latter conditions it will be noticed that positive ionization had higher counts than negative ionization; this is due to the greater difficulty in maintaining negative ionization.

The fans in the ion generators were operative also with ordinary air, in order to provide always the same degree of air movement.

Experimental procedure

Test subjects

Sixteen subjects were used in the ionization studies. Only fifteen were taken into consideration, as one attended only half of the warm tests. Each subject underwent a general physical examination, and basal metabolism tests were made on ten of them which proved to be within normal limits. Seven of the fifteen subjects participated in the day tests and eight in the evening tests. During the tests the subjects wrote, read and played chess.

Periods of exposure

The day group was exposed to four periods of ionization during a day, each lasting 80 or 100 min. The night group which started its session in the late afternoon was exposed to two periods only. The sequence adopted consisted in permutations of background, positive and negative ionization. The day group entered the test room at 9.00 a.m., and left at 12.00 for a lunch break which lasted to 1.00, and they ended their day's work at 4.00 p.m. The night participants attended from 5.00 to 8.00 p.m.

Sensations recorded

Seven sensations were recorded at 20 min. intervals, and the answers entered into a prepared questionnaire (see p. 192) which consisted of the following scales:

(*a*) General thermal sensation (7 point scale).
(*b*) Humidity sensation (7 point scale).
(*c*) Sensible perspiration (5 point scale).
(*d*) Air motion (six point scale).
(*e*) Pleasantness (4 point scale).
(*f*) Personal feeling or mood (5 point scale).
(*g*) Fatigue (3 point scale).

Oral temperature and pulse rate were taken at 10.00, 12.00, 2.00, 4.00, 6.00 and 8.00.

Changing of ionization

Though dummy switches were operated from time to time, the ionization prevailing at the time of entry was only changed after the 10.40, 2.40 and 6.40 votes. The changeover from one condition to another was surprisingly rapid, and was complete after a few minutes.

ANALYSIS OF DATA AND RESULTS

Total number of votes

In the 'warm' tests (87° F.), all the participants voted on 578 occasions under the influence of positive ionization, on 501 occasions under the influence of background ionization and on 581 occasions under the influence of negative ionization. The corresponding figure for 'Comfortable' tests (78° F.) are: 248, 378 and 252.

The sum of the six figures times 7 gives the total number of votes on which this study is based: $2{,}538 \times 7 = 17{,}766$.

High and low votes in sensations

In the 'warm' tests, the lowest vote in most sensations indicates the best feeling. This applies to the scales of thermal sensation, sensible perspiration, pleasantness, mood, fatigue, pulse rate and oral temperature. With humidity sensation it could be argued whether 'dry' or 'humid' should be considered as up or down from 'normal'. Though either view could be adopted, the 'drier' vote is usually regarded as the preferable. This brings the humidity votes in line with the other votes. The only exception is air motion. Stagnant air ('1') on our 6 point scale causes an unpleasant sensation; as the votes at the other end of the scale ('wind', '5' and 'strong wind', '6') were never encountered, it follows, that over this limited range, rising scale values are associated with better feelings.

Methods applied

Four different methods were applied to assess the effect of ionization.

(1) A test based on scores assigned to mean votes cast under the influence of the three ionization levels. The distribution of these scores was compared with the

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distribution which would have been obtained if ionization had no effect. Scores of all sensations, pulse rate and oral temperature of all subjects were pooled for each of the three ionization levels.

(2) A test based on the distribution of the lowest means occurring under the influence of the three ionization levels. The distribution of these lowest means was compared with that assuming no effect of ionization.

(3) Differences between grand means were tested for significance.

(4) A test to assess individual preference towards the three ionization conditions, using all sensations, pulse rate and oral temperature.

(1) *Method of sum of scores*

To each lowest mean of each person a score of '1' was assigned, to each intermediate a score of '2', and to each highest mean a score of '3'. For example: Subject no. 7 had the following mean thermal votes for the three ionization levels: negative 6·630, background 6·912, positive 6·400, to which the scores were assigned: negative '2', background '3' and positive '1'.

In case of two means equally low, the scores are: $(1+2)/2 = 1{\cdot}5$, in case of two equally high: $(2+3)/2 = 2{\cdot}5$, and in case of all three equal: $(1+2+3)/3 = 2$.

The sum of all scores for all nine qualities (seven sensations, pulse rate and oral temperature) for all fifteen persons equals:

$$(1+2+3)\times 9\times 15 = 810.$$

If ionizing had no effect, the number of scores for each ionization level would have to be equal, namely, $810/3 = 270$.

The sums of scores found in the 'warm' tests were: positive, 259·5; background, 311·5; negative, 239·0.

By applying a χ^2 test it was found that the distribution of sums of scores obtained differed significantly ($P = 0{\cdot}0078$) from that assuming no effect of ionization.

The same test applied to the 'comfortable' data yielded a probability of 0·5067.

(2) *Method of sums of lowest means*

The lowest means for each person and each quality were simply counted, without assigning scores.

In this instance, assuming no effect of ionization, the sum of lowest means for fifteen persons and nine qualities equals $15\times 9 = 135$, or for each ionization level $135/3 = 45$.

The frequencies actually found in the 'warm' tests were: positive, 49·0; background, 28·5; negative, 57·5.

Applying the χ^2 test it was found that the above distribution differed significantly ($P = 0{\cdot}0087$) from that expected when assuming no effect of ionization. Performing the same test on the 'comfortable' data, no significant difference ($P = 0{\cdot}271$) was found.

The advantage of the method of lowest means is that no scores have to be applied.

Its disadvantage is that it fails to take into account the second (intermediate) and the highest means.

Methods (1) and (2) only show whether the distribution differs from that assuming no effect of ionization. They are, however, unable to indicate to which sensations and persons the discrepancies are due. Scores also fail to indicate the size of the difference which led to the scores.

Subject No. 7, for instance cast the following mean thermal votes in the 'warm' tests: positive, 6·630; background, 6·912; and negative, 6·400. Differences much smaller than the above would have led to the same scores, namely '2' '3' and '1'.

(3) *Significances of differences between grand means*

By averaging all votes cast by all subjects at each ionization level, grand means were obtained which are shown in Table 1. The differences between grand means were tested for significance, and only a probability of less than 0·001 was considered significant.

Table 1. *Grand means for the three levels of ionization ('background' is listed in two identical columns) in warm and comfortable tests.*

(Diferences between the grand means are entered nearer to the lower mean (exception: air motion). Significant differences only are marked with the letter S.)

		Ion polarity										
Sensation		Background	Background–Positive		Positive	Positive–Negative		Negative	Background–Negative		Background
Thermal	Warm	6·162	—	S0·180	5·982	—	0·034	5·948	—	S0·214	6·162
	Comfortable	3·818	—	0·082	3·736	0·016	—	3·752	—	0·066	3·818
Humidity	Warm	4·587	0·059	—	4·646	—	0·118	4·528	—	0·059	4·587
	Comfortable	4·005	—	0·009	3·996	0·026	—	4·022	0·017	—	4·005
Perspiration	Warm	1·380	—	S0·192	1·188	—	0·023	1·165	—	S0·215	1·380
	Comfortable	0·034	0·016	—	0·050	—	0·032	0·018	—	0·016	0·034
Air motion	Warm	2·067	—	0·046	2·113	—	—	2·113	—	0·046	2·067
	Comfortable	3·217	0·044	—	3·173	0·060	—	3·113	0·104	—	3·217
Pleasantness	Warm	2·808	—	S0·120	2·688	—	0·098	2·590	—	S0·218	2·808
	Comfortable	1·481	0·039	—	1·520	0·075	—	1·595	0·114	—	1·481
Mood	Warm	3·043	—	S0·139	2·904	—	0·026	2·878	—	S0·165	3·043
	Comfortable	2·870	—	S0·162	2·708	0·090	—	2·798	—	0·072	2·870
Fatigue	Warm	2·128	—	S0·239	1·889	0·103	—	1·992	—	S0·136	2·128
	Comfortable	1·642	0·114	—	1·756	0·008	—	1·764	0·122	—	1·642
Pulse rate	Warm	81·178	—	0·864	80·314	0·207	—	80·521	—	0·657	81·178
	Comfortable	78·462	—	2·443	76·019	2·148	—	78·167	—	0·295	78·462
Oral temperature	Warm	98·787	—	0·031	98·756	—	0·016	98·740	—	0·047	98·787
	Comfortable	98·621	—	0·043	98·578	0·028	—	98·606	—	0·015	98·621

From this table it would appear that the subjects, in the 'warm' tests, felt cooler, perspired less, felt more pleasant, were in a better mood and felt less fatigued under the influence of ionization.

The cooling effect can be estimated in degrees F. from Koch *et al.* (1960) where, at 50% r.h., 87° F. a decrease of 0·18 sensory unit corresponded to a decrease of 0·89° F., and a decrease of 0·21 sensory unit corresponded to 1·05° F.

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(4) *Test to assess individual preference*

The lower means always (exception: air motion) indicate the preferred condition. Positive as well as negative means were compared with background means by calculating their differences. The significances of these differences were determined and the exact probabilities found. These probabilities were combined into a single estimate of individual preference, according to the method of Fisher (1946), which is based on the product of these probabilities. The natural logarithm of each probability is doubled and its sign changed. This gives the equivalent value of χ^2 for 2 degrees of freedom. Any number of such values may be added together to give a composite test, using the table of χ^2 to examine the significance. If the probabilities to be combined average around $P = 0{\cdot}3$, the combined probability is still around 0·3.

Table 2. *Tests for individual preference*

(This table indicates the steps in calculating individual preferences of two subjects, one preferring ionized air (No. 7), and one preferring air not enriched with ions (No. 41). The first column shows the mean votes for thermal sensation, cast at the three ionization levels. The second column lists the differences between the mean votes for 'Background' and 'Positive', and 'Background' and 'Negative' which are entered under the ionization which yielded the lower (exception: air motion) mean. The third column shows the exact probabilities, that these differences might have occurred by chance. The fourth column contains the chi-squares of these probabilities calculated by taking twice the negative natural logarithm. The fifth column shows the sum of chi-squares for all qualities appearing under each ionization level. The last column indicates the probability corresponding to the sum of chi-squares, taking two degrees of freedom for each entry.)

	(1) Mean vote of thermal sensation	(2) Difference	(3) Probability	(4) χ^2	(5) Sum of χ^2	(6) Probability corresponding to (5)
			Subject no. 7			
Positive	6·630	0·282	0·0104	9·1319	48·1864	<0·001
Background	6·912	—	—	—	6·7967	0·5602
Negative	6·400	0·512	0·00001	27·631	50·5623	<0·001
			Subject no. 41			
Positive	6·083	—	—	—	1·1877	0·5589
Background	5·944	0·139	0·4436	1·6257	50·9197	0·0091
		0·250	0·1685	3·5616		
Negative	6·194	—	—	—	2·0632	0·7241

The resulting differences, their probabilities and χ^2 are entered under the ionization which yielded the lower (exception: air motion) mean. The χ^2 appearing under each ionization are added and looked up under the appropriate number of degrees of freedom, namely 2 for each entry.

Two examples will illustrate this, one of subject no. 7, preferring ionized air, and one of subject no. 41, preferring background.

These tests of individual preferences indicated that six out of fifteen persons clearly preferred ($P < 0{\cdot}001$) ionized air in the 'warm' tests. Four persons (nos. 7, 27, 29 and 33) preferred positive or negative to background. Two persons (nos. 31 and 39) preferred positive ionization to background. One person (no. 41) felt best without ionization ($P = 0{\cdot}0091$).

DISCUSSION

Differences in air temperatures at the three ionization levels can be ruled out as cause of the significant differences between mean votes. The mean air temperature in the 'warm' tests was: positive, 86·9° F.; background, 87·006° F.; negative, 87·01° F.; relative humidity was kept at 50%, with a fluctuation of plus/minus 2%; air motion was also constant in all tests (*c*. 28 ft./min.).

From previous work it was known that votes changed during a 3 hr. session. In the present experiments two different ionization conditions were tested in each 3 hr. session. An equal number of experiments for each of the three ionization conditions was therefore performed in the first and the second half of the three hour session. For instance, in the 'warm' tests:

	First half	Second half
Background	8	8
Negative	9	9
Positive	9	9

Friedman's method of ranks, as described by Siegel (1956) was also tried when evaluating the data. In this method the χ^2 for ranks are obtained.

According to Friedman's method only two sensations in the 'warm' tests, namely pleasantness (P between 0·05 and 0·02) and sensible perspiration ($P < 0{\cdot}001$) would seem to be affected by ionization.

On the other hand, summing up all χ^2 obtained by Friedman's method (nine qualities and fifteen subjects) yielded a probability of less than 0·001. This summing up of χ^2 is analogue to the aforementioned procedure of sums of scores, in which a probability of 0·0078 was obtained.

Friedman's method of ranks has to be applied to data where the use of parametric methods is not really warranted. However, methods based on scores or ranks are hardly tools as powerful as a parametric method, since scores as well as ranks fail to indicate the true differences in the original data from which they were developed; they indicate rather whether the null hypothesis has to be rejected.

As to determine whether parametric methods are applicable, the distribution of data was tested. It was found, for instance, that the distribution of thermal sensation votes did not differ significantly from the normal distribution; P between 0·5 and 0·3.

For the calculations of the significances of differences of means we used single votes as single observations, and a probability of less than 0·001 was considered the limit of significance.

Significances of differences between grand means, taking single tests, not votes, as single observations, were also calculated. The number of tests was: positive ionization, 126; background ionization, 111; negative ionization, 125.

For instance, the differences betweeen grand means of thermal sensation in the 'warm' tests were significant: background minus positive yielded a P of 0·0375 and background minus negative yielded a P of 0·0136.

Yaglou *et al.* (1933) observed a 'general cooling effect' under the influence of ionization; this was most apparent in the summer tests, when the skin of the subjects was more or less moist. This effect was noted in 5·4 % of their observations with positive ionization and 12·9 % with negative ionization. The above observations are in line with the significant lowering in thermal and sensible perspiration votes found in the 'warm' tests in the present investigation.

SUMMARY

1 Fifteen apparently healthy persons were exposed to air enriched with positive or negative ions at 78° F. and 87° F. Average ion counts at 78° F. were 12,324 positive ions per ml. and 5,451 negative ions per ml. The averages at 87° F. were 14,865 positive ions per ml. and 5,442 negative ions per ml. Relative humidity was kept at 50 % and air motion was 28 ft./min.

2. Seven sensations related to comfort (thermal sensation, humidity sensation, sensible perspiration, air motion, pleasantness, mood and fatigue) were recorded, pulse rate and oral temperature were measured.

3. In the experiments at 78° F. mood was improved ($P < 0{\cdot}001$) by positive ionization. All other qualities remained unaffected by positive ionization. No effect was found under negative ionization at the ion concentration applied.

4. In the experiments at 87° F. five sensations (thermal sensation, sensible perspiration, pleasantness, mood and fatigue) were significantly ($P < 0{\cdot}001$) improved by ionized air. In general, as can be seen from the significant differences between grand means, the subjects felt cooler, perspired less, felt more pleasant, were in a better mood, and felt less fatigued under the influence of air enriched with ions.

Air motion sensation, humidity sensation, pulse rate and oral temperature were not affected by ionization.

5. As different individuals may vary in their response to ionization, individual preferences were tested. These tests indicated that at 87° F. six out of the fifteen persons tested preferred ionized air ($P < 0{\cdot}001$). One person preferred air not enriched with ions ($P = 0{\cdot}0091$).

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NOTE: The form of the questionaire used by the author is printed on the following page.

QUESTIONAIRE

Subject... .... Test no. ....
(Name) (No.)
Date.................................

Entered pretest room...................................a.m., p.m.

Entered test room ....a.m., p.m. Recorder's initials

Observed sensations

Description of sensation scales — Time ... Seat no. ...

General thermal sensation

1. Cold
2. Cool
3. Slightly cool
4. Comfortable
5. Slightly warm
6. Warm
7. Hot

Humidity sensation

The room seems to be:

1. Painfully dry
2. Very dry
3. Dry
4. Normal
5. Humid
6. Very humid
7. Wet

Sensible perspiration

0. Forehead or body dry
1. Forehead or body clammy (surface feels moist to touch)
2. Forehead or body damp (perspiration just visible)
3. Forehead or body wet (sweat covering the surface, frequently in drops)
4. Parts of the clothing wet
5. Most or all of the clothing wet

Air motion

1. Stagnant
2. Still
3. Just perceptible
4. Breeze
5. Wind
6. Strong wind

Pleasantness

1. Pleasant
2. Indifferent
3. Unpleasant
4. Very unpleasant

Personal feeling or mood

1. In very high spirits
2. In good spirits
3. Normal mood
4. In low spirits
5. Depressed

Fatigue

1. Feel fresh
2. Indifferent
3. Fatigued

Do you believe that there were any special circumstances other than environment which influenced the answers you gave above?.........Yes.........No?