Jordan's

TROPICAL HYGIENE AND SANITATION

W. Wilkie

FOURTH EDITION

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PREFACE TO THE FOURTH EDITION

It is now 25 years since this book was first published and during all this time it has served as a useful text-book and reference book for Health Inspectors and other subsidiary health staff in tropical and sub-tropical countries. Its primary aim is, as it always has been, to provide for the student a simple, practical book which, accompanied by tuition, will enable him to follow his profession with interest.

The favourable reception accorded the Third Edition has necessitated the production of yet another edition. In this Fourth Edition many additions have been made, chiefly to the chapters on Water, Refuse Disposal and the Destruction of Rats. Eleven new drawings have been added.

The main framework of the book has proved suitable to students and has therefore been left largely unaltered. It is hoped that the new edition will prove as popular as the preceding ones and that, in its revised form, it will appeal to students and others, not only in Africa but in all of the developing countries.

My thanks are due to Dr. H. Dix for his advice on alterations to the chapter on Health Education.

W WILKIE

Kabul, Afghanistan
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TROPICAL HYGIENE AND SANITATION

CHAPTER I

AIR AND VENTILATION

ALL known material things come into one of three classes: Solids, Liquids, Gases.

A solid has definite shape and size, which it retains unless force of some kind is applied to it—e.g., a stone or a speck of dust.

A liquid has definite volume, but takes the shape of any vessel in which it is contained. If the vessel is not full, the surface of the liquid remains horizontal; the liquid does not expand to fill the vessel.

A gas has neither shape nor volume. It expands to fill any vessel in which it is contained. A fluid may be kept in an open vessel; a gas would immediately escape into the surrounding air.

PROPERTIES AND NATURE OF GASES

Gas has no shape; it takes that of any vessel in which it is contained.

Suppose we take two pint bottles filled with gas and then release the gas from one of these into another bottle, the capacity of which is 20 pints. The gas from the smaller bottle will expand to fill the larger bottle. The shape and size of the gas have altered. The **weight** of the gas, however, remains the same. If we weigh the gas in the larger bottle and then that in the smaller bottle, we find that the weights are equal; we also find that the weight of 1 pint of gas from the 20-pint bottle is equal to one-twentieth of the weight of the gas in the pint bottle.

If we take gas from a large vessel and put it into a smaller one, we say that the gas has been **compressed** into the smaller space. If we take gas from a small vessel and put it into a larger one, we say that the gas has **expanded** into the larger space.

As gases are compressed they weigh more, and as they expand they weigh less, volume for volume.

COMPOSITION AND PROPERTIES OF AIR

Air as a Mixture of Gases.

Air is composed of several gases, which are well mixed together, but which do not combine to form a new kind of gas. It is invisible, but its presence is made evident to us in other ways. We are conscious of inhaling it when we breathe; we can feel it blowing against us when it is in motion, either as wind or as a draught; we can see the movement of grass and trees and of ripples on water caused by it.

Air takes up Space.

To prove this, take an "empty" jar—i.e., a jar filled with air; turn it upside down and press it under the surface of a bowl of water. You will find that the water in the bowl does not rise and fill the jar. The air in the jar prevents it from doing so. Try the same experiment with a jar which has a hole in the top. You will find that the water rises quickly and fills the jar, driving out the air through the hole in the top.

Air has Weight, can Expand and is Compressible.

Take a large bottle fitted with an airtight cork, and weigh it carefully. Remove the cork and heat the bottle. Now replace the cork quickly and reweigh the bottle; it will be found to be lighter than it was. As the weight of the bottle is constant, the difference must be due to the change in the air in it. What has happened is that the air in the bottle **expanded** when heated, and therefore required more space; some of it escaped into the surrounding air. When the bottle was weighed the second time there was less air in it than when weighed the first time. Therefore the reduction of weight was due to a reduction in the weight of the air in the bottle, and this experiment demonstrates two things:

(a) That air expands when heated.
(b) That air has weight.

If the cork of the bottle is fitted with a valve of the type found on bicycle tubes, another experiment may be tried.

Allow the bottle to fill with air. Put in the cork and weigh the bottle. Now pump in more air with a bicycle pump. Weigh the bottle again; it will be found to be heavier than it was before the extra air was forcibly pumped in. The air which was originally in the bottle has become more tightly packed, or **compressed**, to allow for the entry of more air. This experiment demonstrates two things:

(a) That air has weight.
(b) That air is compressible.

Air varies in Weight According to (a) its Temperature and (b) its Pressure

(a) **According to its Temperature.**—In the above experiment it has been shown that air expands when heated, and that a given volume of heated air weighs less than the same volume of cold air. This is what we mean when we say that hot air weighs less than cold air. It follows that in calculating the weight of a given volume of air we must know its temperature.

(b) **According to its Pressure.—By pressure we mean** the force of the weight of one body acting against another body. If you stretch out your arm and someone places a large stone on your hand, you will feel that the weight of the stone is forcing your arm down. You can feel the pressure of the weight, and if you wish to keep the stone in the same position you must use the strength of your arm to do so; in other words, you must use upward pressure to counteract the downward pressure of the weight of the stone.

Take a pair of scales and put a 10-pound weight on each side. The scale will be exactly balanced because there is a pressure of 10 pounds on each side. If you remove one of the weights, the scale on that side will go up and the other containing the remaining weight will go down. Now put your hand into the empty scale and press. When you are exerting a pressure of 10 pounds the scales will stand even. If you use more pressure, you will weigh down your side of the scale; if you use less your scale will be higher than that containing the weight.

In the case of the second experiment with the bottle of air, where extra air was forced into the bottle with a pump, we found that there was an extra weight of air in the bottle, although the volume remained the same. We now know that extra weight means greater pressure, and that to calculate the weight of a given volume of air we must know not only its temperature, but also its pressure.

ATMOSPHERIC PRESSURE

We call the air in which we live **the atmosphere.** The atmosphere extends to a height of from 40 to 50 miles above the surface of the earth, and, as it has weight, it exerts pressure on that surface. At sea-level **atmospheric pressure** is at its greatest, and it becomes less as the ground rises above this level. If we climb a mountain or go up in an aeroplane the atmospheric pressure becomes reduced as we rise, because there is less air above us.

Atmospheric pressure is about 14.7 pounds per square inch at sea-level, and at a height of 2,640 feet (half a mile) it is nearly one-tenth less.

There is an instrument which is used for measuring air weight or atmospheric pressure. This is called **the barometer.**

You can make a simple barometer for yourself. Take a tube closed at one end and fill it with mercury. Close the tube completely by placing your finger tightly over the open end. Now invert the tube into a small basin of mercury and take away your finger. You will find that, although some of the mercury has run out, a column of it remains in the tube. What is keeping it there? It is the pressure of the atmosphere on the surface of the mercury in the basin in which the tube is standing.

Repeat this experiment with another tube, and you will find that the second column of mercury is of the same length as in the first tube. This means that you have **a measure** of the atmospheric pressure.

A column of mercury such as this with lines marked on the tube to indicate the rise or fall of the mercury is a barometer, and can be used to measure heights. Suppose that the mercury in a barometer stands at 30 inches at sea-level; if the barometer is taken up to a height of 5,000 feet the mercury will be found to have fallen to 25 inches. The explanation is that there is less atmospheric pressure on the surface of the mercury in the bowl, and the column of mercury which is pushed up by the weight of the air is correspondingly shorter.

To calculate the Weight of Air.—For general purposes we may say that the weight of 13 cubic feet of air is 1 pound. We know, however, that the weight of air depends on its temperature and pressure.

For purposes of calculation we take the atmospheric pressure at sea-level—*i.e.*, 14.7 pounds per square inch —as a standard. The weight of any quantity of air at this pressure and at any given temperature may be ascertained by using a formula.

The formula for calculating the weight of a cubic foot of air at ordinary atmospheric pressure and at any given temperature (degrees Fahrenheit) is:

$$W = \frac{14.7}{0.37\,(T + 460)},$$

where W = weight of 1 cubic foot of air in pounds,
T = temperature (degrees Fahrenheit).

Example.—What is the weight of 1 cubic foot of air at a temperature of 70° Fahrenheit?

$$\text{Weight} = \frac{14.7}{0.37\,(70 + 460)} = 0.07496 \text{ pound.}$$

THE COMPOSITION OF AIR.

Air consists of a number of gases, well mixed together but not chemically combined. By this we mean that the various gases have not joined together to form a new gas, but remain in their original form and retain their own properties.

The most important of these gases are **oxygen, nitrogen, carbon dioxide** and **water vapour.** The proportions vary a little, but pure air may be said to be composed by volume as follows:

Oxygen	20.96	per cent.
Nitrogen	79.00	„ „
Carbon dioxide	0.04	„ „
Total	100.00	„ „

Water vapour varies considerably in amount according to conditions which will be explained later.

The Gases of the Air.

Oxygen.—Oxygen is an element—that is, a simple substance which cannot be split up into other substances. It has no colour, no taste, and no smell. **It supports combustion**—*i.e.*, it is necessary for the production of flame or heat. It is required by animals and plants to sustain life which is dependent on the process of combustion. It readily combines with many other substances, heat and light being given out when the combination takes place. Heat only is produced if the combustion is slow. The compounds which result from the combination of oxygen and other substances are called **oxides.**

For example, if any substance containing carbon is burnt, the carbon in it is released and combines with the oxygen in the air to form carbon dioxide. During the process of burning, which is also called combustion, heat and light are given off, but heat only if the process is very slow.

Oxygen is necessary for Combustion.—To show this, burn a candle in an enclosed space. As soon as the oxygen in the air in the enclosed space is exhausted, combustion stops and the candle ceases to burn. If the candle be lighted in the open, it will continue to burn to the end, as it receives continuous supplies of oxygen from the air around it. We can put out any fire by excluding air, because by cutting off the supply of oxygen the process of combustion cannot continue.

Nitrogen.—Nitrogen is also an element; it is also colourless, tasteless and odourless. In other respects it is quite unlike oxygen. It does not support combustion. It is sometimes called the inactive part of the air because, in this form, it is not used by animals or plants, nor does it combine directly with the other elements.

It has a very important use, however; it dilutes the oxygen in the air. Any substance which will burn in air burns more brightly in pure oxygen because the process of combustion is more rapid. Thus if the air were composed of pure oxygen, combustion would proceed at a much greater speed and life as we know it would be impossible. As it is, about four-fifths of the volume of air is nitrogen, and plants and animals thus get the right amount of oxygen necessary to sustain life. Nitrogen exists in all living matter, but it is in the form of compounds of nitrogen only.

Carbon Dioxide.—Carbon dioxide is a **chemical compound.** It is made up of two elements, oxygen and carbon, which combine together to form a new substance. This substance has properties differing entirely from those of the two elements of which it is composed.

It is important to realise the difference between a simple mixture and a chemical compound. As we have seen, air is a simple mixture of gases.

In a chemical compound the proportions never vary. Carbon dioxide is always composed of 1 part of carbon and 2 parts of oxygen, and in no other proportion is it possible for this gas to be formed. Thus its chemical formula is written as CO_2—carbon 1 part, oxygen 2 parts.

The oxygen which forms part of carbon dioxide loses its individual properties when thus combined chemically. It cannot now be used, as is the oxygen in the air, to support life or combustion.

Carbon dioxide will not burn: it will not support life or combustion.

Carbon dioxide is formed when the carbon in any substance is combined with oxygen as in the process of burning. It is given off in the breath as a waste product of the burning processes in the body. Plants, too, give off carbon dioxide when they breathe.

Water Vapour.—If we pour water into a dish and leave it exposed to the air, the water will, in time, disappear. If we hang wet clothing up in the air the water in the clothing will disappear. What has become of the water in both these cases? It has been taken by the surrounding air in the form of water vapour. We say the water has **evaporated**, meaning that it has turned into a gas and mingled with the air around it. A certain amount of heat is necessary to make the process of evaporation possible, and, as a rule, the greater the heat, the quicker the process.

You can test this by heating the water in your dish; it will disappear much more quickly than it would if left unheated. If evaporation is taking place very rapidly, clouds of steam arise and then disperse into the atmosphere.

We can reverse the process of evaporation by causing this steam to strike a cold surface. If you hold a cold plate in front of the spout of a kettle from which steam is coming, the plate immediately becomes wet; the water vapour has turned into water again. This process we call **condensation.** Clouds and mist are composed of water vapour, which, if cooled, turn into water again and fall as rain.

Think of the great surfaces of water—lakes, rivers, and seas—which are continuously exposed to the air and to the warmth of the sun; then you will understand why there must always be water vapour in the air. Its function is very important. Without it everything would be dried up.

The quantity of water vapour in the air is not constant, but varies with the temperature of the air and the local conditions; for example, the higher the temperature, the more water vapour the atmosphere can hold.

If the air contains the maximum amount of water that it can hold at any given temperature, it is said to be **saturated with moisture.** Air which is so saturated cannot take up any more water vapour, and the process of evaporation ceases. Thus wet clothing remains wet, and water in open dishes and pools remains there. The air is, however, very seldom completely saturated.

The ratio between the actual amount of water vapour present in the air and the maximum amount that the air can hold at a given temperature is called the **relative humidity of the air.** Thus, if the maximum amount is taken as 100 and the atmosphere contains only half that amount, we say that the relative humidity of the air is 50 per cent.

The moisture content of air may be expressed in another way viz., **absolute humidity.** This term refers to the **weight** of moisture contained in a **known volume** of moist air.

When warm, moist, unsaturated air is cooled to a point at which further cooling will cause condensation the temperature at that point is known as the **dew point.** Condensation sometimes occurs on cold surfaces inside a building. This is the result of moist air inside the building being cooled below its dew point and so depositing its moisture.

Summary.

(*a*) A gas has no definite shape or volume. It expands indefinitely if not confined, and may easily be compressed into a smaller volume.

(*b*) Gases have weight and exert pressure. The weight varies with the temperature.

(*c*) The gases of the air form a simple mixture, not a chemical compound.

(*d*) Air consists mainly of oxygen and nitrogen, with smaller quantities of water vapour and carbon dioxide.

(*e*) Oxygen is the active part of the air.

(*f*) Nitrogen is **inactive**; it serves to dilute the oxygen, and it cannot support life or combustion.

(*g*) Carbon dioxide is necessary to plant life.

Exercises.

1. What is the composition of ordinary atmospheric air?
2. What are the properties common to all gases?
3. Why do we say that air is a mixture of gases and not a chemical compound?
4. What is meant by "atmospheric pressure"?
5. Why is the pressure of the atmosphere less at the top of a mountain than at sea-level?
6. What is the effect of heat on a gas?
7. What are the properties of (*a*) oxygen, (*b*) nitrogen? Explain the function of each of these gases in the atmosphere.
8. What is water vapour? What would happen if there were none in the atmosphere?
9. What do you understand by the "relative humidity" of the air?

HOW AIR IS POLLUTED

Air is rendered impure by—

(*a*) Respiration.
(*b*) Combustion.
(*c*) Decomposition.
(*d*) Manufacturing processes.

(*a*) **Respiration.**—The air which we breathe undergoes a change within the body. Oxygen is taken up by the blood, and the waste products of combustion—carbon dioxide, water vapours and other matters—are exhaled.

The average composition of pure air is contrasted with that of expired air in the following tables:

	Oxygen (Per Cent.)	*Nitrogen (Per Cent.)*	*Carbon dioxide (Per Cent.)*
Pure air	20.96	79	0.04
Expired air ...	16	79	3.4

Note that in expired air the oxygen is decreased about 4 per cent. and the carbon dioxide is increased about 4 per cent. The oxygen is united with the carbon in the tissue, heat and energy have been produced, and the waste product, carbon dioxide, is given off in the expired air.

Note also that the amount of the nitrogen, the inactive part of air, remains unchanged.

(*b*) **Combustion.**—Fire and lamps need oxygen in order that they may burn; they take the oxygen from the air, and in the process of burning produce carbon dioxide and water vapour.

Fires in buildings not provided with proper flues pollute the air with smoke, which causes irritation of the eyes and lungs, thus making the entry of disease germs easy.

(*c*) **Decomposition.**—By decomposition is meant the breaking up of organic or inorganic matter.

Tiny particles of matter are constantly floating about in the air. We see them when they settle on smooth surfaces as "dust" or suspended in the air when a beam of sunlight entering a darkened room through a small hole illuminates them.

These particles of matter, or dust, are of two kinds —**organic** and **inorganic.** They are both products of decomposition.

Inorganic dust is made by the grinding and breaking up of rocks and other non-living solid matter. We can see this happening every day on roads. Road surfaces, originally stones (rock of some sort), are ground to powder by the pressure of the traffic which passes over them. This dust is continually being blown up into the air by the wind, and the particles are so light that they float in the air and are dispersed over wide areas.

Organic dust is composed of particles of matter which come from the decomposition or breaking up of animal or vegetable matter. It consists of pollen from plants or dead tissue (animal or vegetable), the dried cells of which are blown about by wind.

Air is also vitiated by the gases which are generated when animal and vegetable matters decompose or decay. These gases, although they arise from the decomposition of organic matter, are themselves inorganic.

(*d*) **Manufacturing Processes.**—Where machinery is used the air may be vitiated by smoke or by exhaust gases, or both.

The exhaust or waste gases from motor-car engines and others of the same type (internal combustion) contain the poisonous gas carbon monoxide (CO).

Offensive trades, such as blood boiling, soap-making, bone-boiling, hide-drying, gut-scraping and so on, vitiate the air by foul smells and organic matters.

EFFECTS PRODUCED BY VITIATED AIR

When the air of occupied rooms is not replaced it deteriorates and conveys a sense of discomfort to the occupants. The usual symptoms produced are flushing of the cheeks, followed by headache, sweating and perhaps giddiness.

It was once believed that an organic poison, exhaled in the breath, was responsible for the harmful effects produced by the vitiated air. Later it was thought that the harmful symptoms were caused by a decrease in the oxygen content of the air and an increase in the carbon dioxide content. All of these theories have since been refuted. An oxygen content as low as 16 per cent produces no distress, although breathing becomes rapid. Men working in carbon dioxide concentrations of 1 per cent, as for example in breweries, remain healthy. Under very bad conditions in public cinemas etc., it has been noted that the oxygen content of the air is seldom reduced by as much as 1 per cent nor does the carbon dioxide content often reach 0.5 per cent.

In 1883 a suggestion was put forward that the harmful effects produced by vitiated air were due to physical and not chemical changes. Later Dr. Leonard Hill, by experiment, proved this to be correct when he placed several of his students in an airtight chamber. He recorded a rise in the carbon dioxide content of the air inside to 4 per cent and a decrease in the oxygen content to 16 per cent, and a wet bulb thermometer reading showed 85°F. The discomfort felt by the students was relieved by using an electric fan to produce air