SCHOOL VENTILATION.

By ALFRED GREENWOOD, M.D., D.P.H.,
Medical Officer of Health for Blackburn.
 (MEMBER.)

ABSTRACT.

ALTHOUGH the number of papers and discussions on this important subject is large, the recent combination of the education authority and the sanitary authority has again brought the question into prominence.

In many towns the medical officer of health has already been appointed medical officer to the education authority.

Probably in many cases the new authority will require a report upon the condition of the school buildings under its jurisdiction, and in my own case I was requested, as medical officer of health and as medical officer to the education authority, to prepare a detailed report upon the sanitary conditions of the fifty-two public elementary schools at Blackburn.

I thought that it would be of some interest to this Congress if I gave a short account of the methods and results of my investigations.

I first prepared a spot map showing the name and exact locality of the fifty-two schools, and then proceeded to examine each school in detail, covering every possible sanitary condition. Also, a plan drawn to scale (30 ft. to 1 in.) was prepared at each school.

In describing the schools seriatim the following points were noticed:—A brief description was first given dealing with the EXTERNAL conditions, such as condition of buildings, playgrounds, sanitary conveniences, etc. Then measurements and observations were recorded of the INTERNAL conditions, such as heating, natural and artificial lighting, cloak-room accommodation, walls, floors, etc. Each room was then dealt with separately in respect to floor space, cubic space, ventilation (inlets and outlets), and lighting, per scholar. The special conclusions and recommendations for each school followed next, and the plan drawn to scale showing the arrangement of the rooms completed the description of the school.

159 samples of school air were analysed by Pettenkofer's method for

the amount of carbon dioxide gas, and the air of the schools was also examined bacteriologically.

The subject of efficient ventilation of schools is an exceedingly difficult problem. It has involved a large expenditure of time and money. Installations have been fixed at great cost without much satisfaction, and even now there are many diverse opinions on this matter.

All will agree it is extremely important that the air of schools during school hours should be as pure as possible. There is no doubt that bad ventilation conduces to the spread of infectious diseases, as measles, diphtheria, scarlet fever, tuberculosis, etc., and also prevents the maximum benefit of the teaching from an educational point of view.

It is well known that persons engaged in out-door occupations, such as farmers, labourers, etc., are stronger in physique than those who are compelled to follow sedentary occupations inside, such as clerks, etc.

As the latter cannot otherwise earn their living, and as children cannot be taught out of doors, every effort should be made to insure that the air which they have to breathe is as fresh as possible.

The average frequency of respirations may be taken to number 16 per minute, and the average volume of each breath as 30 cubic inches. The volume of air expired is about 17 cubic feet per hour. This air contains .6 cubic feet of carbon dioxide gas as well as moisture, and has an increased temperature (78° to 81° Fahr.). If it were possible to take this away immediately, before it could mix with the other air, 17 cubic feet of fresh air supplied per head per hour would be sufficient. As this cannot be done, one must decide how much fresh air is required to dilute the impure air suitably. Generally speaking, the air of a room cannot be changed more frequently than three times in one hour. This, of course, does not apply to very hot weather. The air should be able to move freely about a room, as it may stagnate in recesses.

I am of opinion that in many cases sufficient advantage is not taken of the means of natural ventilation already present.

NATURAL VENTILATION.

This is the system that obtains in the majority of the Blackburn schools, and it is dependent upon wind, currents of air due to differences in temperature of the air, inside and outside, and also upon the other currents due to the heat of fires and gas jets.

When air is heated it expands, and when it cools it contracts. Hot air rises to the upper parts of a room, and cold air falls to the lower parts. Moist air also rises, as the vapour of water is lighter than air. The outlet

openings should, therefore, be near the highest parts of a room, and the inlet openings for fresh air should be arranged in such a way (about 5 ft. above the floor) that the air is properly diffused without draughts, and so that it tends to go upwards, in order that before descending to the lower parts of the room it mixes with the other air in the room. The introduction of fresh air should be distributed at several points along the side of the room. Air finds its way into a room by the doors and windows, and in a less degree by the ceilings, walls, and floors.

Windows should be made to open at the top and at the bottom. The lower portion should be constructed like a sash window, and the upper parts should be fixed with sides and hinges below, so as to be capable of being pulled inwards to the room. The hinges should be housed so that when the hopper is open there is no space between its lower part and the adjoining part of the window. When open, the result is like a Sheringham valve ventilator in use. These are also known as Hopper windows, and they are an excellent arrangement. When there is cross-ventilation, and windows are arranged in this way, one or more may be kept open at all seasons of the year. These hopper windows cause the air to enter in an upward direction. If the sides above mentioned are not provided, air may flow in at the corners and cause a draught. As to whether windows should be opened at the top or bottom, or on one side of the room or the other will require intelligent action on the part of the teacher.

These hoppers may be placed in upper or lower panes, and should be arranged so that they may be screwed inwards, much or little, according to the force and direction of the wind. The use of poles and window cords to open and shut the hoppers is less efficient than the screw arrangement.

The top of the window may act as an outlet in cold weather, and as an inlet in hot weather. Louvred panes, and various kinds of hit-and-miss ventilators may be used. Also, a board may be placed below a lower sash so as to raise it one or two inches, and provide a space between the upper and lower sashes for the air to enter in an upward direction.

I feel sure that too much stress cannot be laid upon the importance of windows as a means of ventilation. In the natural system, they are by far the most important factors.

In many school rooms all the windows are on one side of the room. In these cases two or three windows should be opened at the top so that some of these openings may act as inlets, and others as outlets.

Ventilating fireplaces have an air chamber behind the grate which is

heated by the fire. Fresh air is admitted from a pipe from outside, it is then warmed, and flows into the room.

Other special means of ventilation are: perforated bricks, Sheringham ventilators, Tobin tubes, McKinnell ventilators, perforated ceilings, etc. Some of these are intended to act as inlets, but under certain conditions they may all act as outlets.

Natural ventilation can only be carried out efficiently when cross-ventilation, or perfilation, is proper.

An open fireplace, *per se*, practically only removes air from the lower parts of the room, although when a fire is burning, about 14,000 cubic feet of air per hour are removed. But if used in connection with a chamber fixed behind the chimney, communicating by its lower and upper parts with the open air and with the upper part of the room respectively, ventilation is rendered more efficient.

In heating by hot water pipes or steam pipes an attempt should be made to arrange them so that they can heat the incoming air, and thus assist ventilation.

Outlet trunks in the ceiling, carried to the outside air, should be constructed in such a way that the air is not cooled too much during its escape. Reliance should, therefore, not be placed upon the temperature of the incoming air to heat the room. The heating of the room should be carried out apart from this by means of fires, hot water pipes, radiators, etc. Inlets and outlets should communicate directly with the external air.

A permanent ventilation inlet opening of $2\frac{1}{2}$ square inches per head, as recommended by the Board of Education, does not seem sufficient for all conditions.

It is generally calculated that one square inch of unobstructed space will only allow 125 cubic feet of air to pass through per hour; so that for every 1,000 cubic feet of air needed, 4 square inches of permanent opening are necessary. This size of opening is necessary under the most favourable conditions, which are rarely present, but in order to obtain good results under less favourable circumstances a larger opening is necessary—even 6 or 8 square inches per head.

The Massachusetts law requires 30 cubic feet of pure air to be supplied each minute per pupil, *i.e.*, 1,800 cubic feet per head per hour.

ARTIFICIAL VENTILATION.

This involves either the propulsion or extraction of air, the establishment of a plenum, or vacuum, in the room to be ventilated. This may be carried out by revolving fans, ventilating ducts, etc.

If extraction be employed, the sources of supplies of fresh air cannot be controlled so easily as in the case of propulsion, where the air is taken from one source only.

The advantages of artificial ventilation are that it is constant under all conditions, and that the air may be suitably prepared as regards heat, purification, and moisture, and also that the source of fresh air and the volume delivered may be regulated.

I think it is unwise to install artificial ventilation with windows which cannot be opened. Doors and windows should be taken into consideration when providing outlets. It is desirable to flush even mechanically ventilated school rooms with open windows during playtimes. Open windows are also extremely valuable in summer weather, whatever may be the system of ventilation.

The question of artificial or mechanical ventilation is also closely associated with the warming of the school.

Care should be taken to prevent the air of the room from becoming too dry, and also to send in sufficient air.

Regarding efficient and mechanical ventilation, it should be remembered that a wrongly applied system may give bad results. Also, if the inlets and outlets are not placed correctly, the air may be driven through without affecting the greater volume of air in the room.

A Select Committee was appointed in 1902, to inquire into the ventilation of the House of Commons. After examining eminent witnesses, they have issued a report which has recently been printed.

This Committee had before them the following proposals for ventilating the House:—

1. The plenum system.
2. Exhaust system, with flow from above downwards.
3. System of inflow at the sides, and outflow at both the roof and the floor.

The Committee could not recommend the adoption of any of these three methods.

They also recommended the institution of an inquiry into problems of ventilation still unsolved, with the view of introducing further improvements in the present system.

Summarising my conclusions regarding the ventilation of Blackburn Schools, I may state that:—

1. Natural ventilation is easy to manage, subject to certain conditions, which I have named, and will be more efficient if the fullest advantage is taken of this means.

2. In some schools provided with mechanical ventilation frequent reliance is placed upon natural ventilation.

3. There is a diversity of opinion as to the value of the known systems of mechanical ventilation, and there is a need for further inquiry upon this subject.

EXAMINATION OF AIR FOR CARBON DIOXIDE GAS.

During December, 1903, and January, 1904, I have analysed 44 samples of outside air in various parts of Blackburn. The average amount of Carbon Dioxide (CO_2) present was 4.37 per 10,000, and the range was from 3.1 to 6.6 parts per 10,000. These 44 analyses included several samples of air taken on foggy days, when the results were 6.1, 6.2, 6.3, 6.5, and 6.6 parts of CO_2 per 10,000. Excluding foggy days the average of my analyses of outside air was 4.02 per 10,000. The highest result I obtained at any time in outside air was 6.6 in 10,000.

The average of six samples of outside air collected in various parts of Blackburn, during the latter half of March, 1904, gave 3.6 parts of CO_2 per 10,000.

As the proportion of CO_2 in the outside air varies on different days, it is necessary to analyse the outside air each day when samples of inside air are examined. This has been done in these experiments.

On foggy days a greater proportion of CO_2 occurs in the air of rooms than on clear days. Also the proportion of CO_2 is greater in a room where the gas jets are burning. One gas jet burning 4 cubic feet per hour consumes the oxygen from 21.32 cubic feet of air.

CO_2 is increased by respiration, combustion, putrefaction, and fog, but diminished by vegetation, rain, high winds, and ventilation.

ANALYSES OF SCHOOL AIR.

The recent investigations into the air of Blackburn schools may be tabulated shortly as follows:—

Number of Analyses.	Average amount of CO_2 per 10,000.
159.	9.69.

or,

Parts of CO_2 per 10,000.	Under 10.	10 to 15.	15 to 20.	20 to 25.
No. of samples examined ... 159	95	52	10	2

Of these 159 samples, 107 were collected in Blackburn Schools during December, 1903, and January, 1904, when fogs occur, and when gas is

often burning in the rooms. The average of these 107 samples showed the presence of 10·4 parts of CO_2 per 10,000, ranging from 4·04 to 20·8 parts.

The remaining 52 samples of school air were collected during the latter end of March, 1904, and the average of these showed the presence of 8·2 parts of CO_2 per 10,000 parts of air, ranging from 4·2 to 15·2 parts.

These results compare very favourably with analyses of school air in other districts, and also with the results of the examination of 88 samples of Blackburn Schools taken by Dr. Wheatley in 1897, which showed on the average a little more than 15 parts of CO_2 per 10,000. This improvement may be explained by the fact that in the intervening period much has been done in the way of improving ventilation openings, and that teachers generally now recognise the importance of this question more than they did several years ago.

I am sure that even better results than those recently obtained would follow if more attention could be given to the means of natural ventilation available.

MR. ARMSTRONG asked whether, in the carrying out of his experiments, Mr. Greenwood found any variation of CO_2 near the ground.

MR. W. KEY (Glasgow and London) said Dr. Greenwood appeared to recommend that the area per child should be increased, but to do so would increase the difficulty. He thought the proper thing to do would be to change the air of the apartment by an apparatus and be independent of the vicissitudes of the weather. He advocated the use of the plenum method of ventilation, and the expense of that could be met by reducing the height of the building. The whole cost of the installation could be met by reducing the space, and the grant earning power of each school would be increased, as with plenum ventilation the scholars did not get colds on leaving the school in frosty weather for the open air, and consequently the benches were always fully occupied. The change of air would be from 12 to 14 times per hour in the summer and 10 times in the winter, this being quite irrespective of outside conditions. It had been found by the late Professor Carnelly that when the air of classrooms was tested, in every case where windows were open on both sides of the apartment to get ventilation, that the teachers whose heads were above the window would get advantage of the fresh air, but that the children who were below the level of the windows were in a stagnant atmosphere. It was invariably found that

through ventilation by open windows did not reduce the number of micro-organisms in the air under the level of the window-sills. These were generally found to exist at the level of the heads of the scholars at a rate of 70 bacteria per litre of air, and the air had a strong school odour. By the downward method of ventilation the purified air reached the nostrils from above, and exhalations were cooled to the same temperature as the incoming air, and were carried away at the floor level. He suggested to Dr. Greenwood that, in dealing with Blackburn, he would find it well to have plenum ventilation. It was an entire misconception on the part of a well-known architect to say that in passing the air downwards into a room it had to meet with an upward current. Where the air was changed ten or twelve times in the hour the temperature was not higher at the outlets than the incoming air (except half a degree) even in a fully-occupied classroom, owing to the rapid renewal of the air, and so there was no upward current to be met. There were a number of other misconceptions about this system, but he asked that it should be given a test.

MR. H. M. ROBINSON asked whether the samples were taken in the schools in the morning or the afternoon.

DR. A. GREENWOOD (Blackburn), replying on the points raised in the discussion, said that he had not taken his samples at different levels in the rooms, but had taken them all at breathing level. He certainly could not agree with Mr. Key who spoke so strongly in favour of the plenum system of ventilation. He hoped to obtain much better results by impressing upon teachers the necessity of using the means of ventilation which were at hand, and he did not feel justified in recommending that any mechanical system should be supplied wholesale, so far as Blackburn was concerned. He did not think the expense would be warranted. He found that in the two mechanically-ventilated schools they had at Blackburn the results were no better than many obtained in the naturally-ventilated schools. The samples were taken at all times, but he could not incorporate the times at which they were taken in the paper. He found that the samples taken later in the afternoon were often the worst.