ON THE
AMOUNT OF CARBONIC ACID
FOUND BY EXPERIMENT
IN THE AIR ON BOARD WOODEN
FRIGATES.

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THE Doris is one of six wooden frigates forming the Detached Squadron, and at present cruising on the West Indian Station. In a ship of this class, with numerous well-arranged windsails, large hatchways, ports and scuttles—provided all these can be kept open, and the windsails are properly trimmed, the ventilation upon the whole is pretty good ; at any rate, it is much better than has been generally supposed.

Numerous carefully conducted experiments I have found most decidedly to point in this direction.

This free and somewhat efficient ventilation of our ships-

of-war is the normal state of affairs just where and when it is needed, viz., in harbour in the tropics. Here, as a rule, ships are a good deal at anchor, and there is really nothing to prevent those in authority from taking full advantage of the somewhat ample means of ventilation at their disposal. But when the rainy season sets in, so many parts of the ship are occasionally obliged to be shut up which during fine weather are always kept open, that the ventilation is apt to become very defective indeed; and the air becomes loaded with all the usual impurities which are always found in overcrowded and confined places. Yet under these unfavorable conditions I have not found that the amount of carbonic acid present in the air on board ship is in excess of that of overcrowded ill-ventilated rooms on shore.

In cold, and temperate climates, too, there is too apt to be a good deal of shutting up of what may be called the natural ventilators of a ship. Nor are windsails made use of quite so frequently as they ought to be, on account of the desire which so generally exists to shut out the cold fresh air. In stormy weather, in the English Channel, on account of almost everything in the shape of an opening being closed, the air on board ship of course becomes greatly vitiated, more especially in the lower parts of the ship. But this is a condition of affairs which is happily somewhat exceptional; if it were otherwise our sailors would suffer terribly.

It must always be borne in mind that the boys for the Royal Navy, who become our seamen as they grow up, are picked from a large number; only the healthiest and most robust being chosen as fit for the service; large numbers being rejected who do not quite come up to the required standard either in physique or measurement, but who nevertheless probably become very useful members of society in other walks of life. We therefore have a right to expect a high standard of health and physique amongst our seamen of the Royal Navy, seeing how very carefully they have been selected. Therefore, when drawing comparisons between our sailors and people on shore of a similar social class, these facts should always be borne in mind.

For instance, I believe that chest complaints are not more common amongst our seamen afloat than they are amongst people of a similar class of life on shore ; whereas one might naturally expect to find a far larger percentage of these affections on board ship, on account of our sailors having to breathe a somewhat vitiated air between decks. But, as I have stated before, as these are all picked men, no useful comparison can be drawn between them and persons living on shore. Moreover, most of the chest complaints of the Navy happen, not amongst our fighting seamen proper, but amongst the stewards and mechanics, who pass their time chiefly down below, and who are not very carefully selected on their first entry, on account of the very different nature of their duties from those of seamen.

Again, the sailors of our Royal Navy and those of the merchant service, with regard to sickness and disease, do not admit of any useful comparison, on account of the very different circumstances which obtain in the two services. In the merchant marine there is not much attention paid to medical examinations of men prior to their entry for a voyage, nor is cleanliness so much attended to as it is in the Royal Navy. Also, in the merchant service, if a man breaks down in health, he can always obtain employment again when he is sufficiently recovered. It is not so in the Royal Navy, for if a man is once invalided out of the service, he can never be employed afloat again.

Ventilation is another matter that is not nearly so well looked after in our merchant ships as it is in ships-of-war. So that in the one service we have men carefully selected, and well cared for in the important matters of food, clothing, cleanliness, and ventilation ; whereas, in the merchant service, these things are not nearly so well looked after. In the Royal Navy there is always at least one medical officer to advise the executive about all sanitary matters.

For these reasons the percentage of sickness amongst our merchant seamen must necessarily be in excess of that which exists amongst the men of the Royal Navy.

As seamen pass so large a portion of their time on the upper deck, they get rid, in a great measure, of the ill effects produced by breathing the impure air below.

With regard to the cubic space required on board men-of-war, to give a fair chance of health to our sailors, 300 cubic feet has been fixed upon as a minimum; but on account of the limited space at our disposal, even this small amount of breathing room can rarely be allowed; whereas on shore 2000 feet is considered necessary, and 800 feet for soldiers in barracks.

In the *Doris*—a wooden frigate, and one of six such ships at present (May 18th, 1873) forming the Detached Squadron, and cruising in the West Indies—121 cubic feet represents the sleeping accommodation for each man berthed on the lower deck, and it is here that the larger portion of the crew sleep.

The *Doris* carries 24 guns, is 2483 tons, and has 800 horse-power. She was commissioned at Devonport in October, 1872, for service with the Detached Squadron. Her complement is 490 officers and men, but with supernumeraries we have generally numbered about 550. She is a good sea-boat, but rolls excessively, probably on account of her massive machinery and heavy guns. She has great beam, very good height between decks; her ports are unusually large, and she has very large hatchways. The men sleep on the main and lower decks.

The main deck, after all the necessary deductions, has an available cubic space of 51,586·1459 cubic feet, and as there are 176 men and boys sleeping on this deck at night, each individual has therefore a space of 287·102 cubic feet.

The lower deck, after all the necessary deductions, has an available space of 42,960·02580 cubic feet, and as the number of the men berthed on this deck at night is 353, each man has therefore 121·7 cubic feet of space. These are the numbers at the present time, but they vary to a small extent occasionally.

Now, as all the ship's company mess on the lower deck, I

have calculated that during meal-times each man and boy has only 80·211 cubic feet of space.

In the sick-bay (situated on the main deck forward), after all necessary deductions for furniture, &c., there is an available space of 1270 cubic feet; it contains sleeping-room for eight people, so that each patient would thus have a space of 158·75 cubic feet.

In the gun-room, where twenty junior officers live, there is an available space, after deductions, of 1000 cubic feet, so that each of these officers has but 50 cubic feet of space during the day. At night these officers sleep on the after-part of the lower deck, a place called the steerage, and then enjoy a space of 121·7 cubic feet.

The engineer officers' mess-place has an available space of 432 cubic feet, and as the number of these officers is four, each has during the day a space of 108 cubic feet. They also sleep in the steerage, and enjoy a space of 121·7 cubic feet at night. The warrant officers have much the same cubic space each as the engineers have.

The cells have a space of 175·168 cubic feet each.

Each of the senior officer's cabins, after deductions, has a space of 290 cubic feet.

So that, so far as sleeping room goes, each man and officer aboard has a breathing space of 121·7 to 290 cubic feet. This undoubtedly is a very small allowance, and far less than what is considered necessary for soldiers in their barracks on shore, in order to give them a fair chance of maintaining their health. Still, on board of a man-of-war the majority of the men are very frequently on the upper deck inhaling a very pure air, and a little of this occasionally taken into the system does away with a good deal of the previous mischief caused by overcrowding in a vitiated atmosphere below.

After numerous experiments made while cruising in the West Indies, and also during a passage from Madeira to Barbadoes, repeated over and over again in all parts of the ship, carbonic acid was the great impurity found in the air between decks and in the lower parts of the ship; the amount varied

at different times and places from 1.03 to 3.21 volumes per 1000, as shown in the accompanying tabulated statement. It was always most abundant on the lower deck and the deeper parts of the ship—in fact, in the worst ventilated parts, and where the men are most crowded at night.

On the upper deck even the amount of CO_2 was above the normal, and this evidently was caused by the heated and vitiated air coming up from below; instead of being only 4 volumes in 10,000, it rose as high as 8 and 9 volumes in the 10,000.

In air expired direct from the lungs into a receiver I found from 54 to 58 volumes of CO_2 in 1000. This was done sometimes to test our apparatus, &c.

Ozone was never present in large quantity, except on the upper deck; there was seldom the smallest trace of it on the lower deck, or in the parts of the ship below that. On the main deck there was a small amount present when the ports were open. I find the amount of carbonic acid in the air on board ships-of-war to be very nearly the same as exists in the air of the most crowded and worst ventilated places on shore, such as workshops, schoolrooms, &c. I have never found the enormous amounts of 18 to 33 volumes per 1000, as recently stated, to exist in the air on board frigates. Such statements seem to me to contain some element of error, as expired air alone contains but 50 to 54 volumes of carbonic acid in 1000.

Recent examinations of the air of public schools in New York show the existence of 0.97 to 3.57 volumes of carbonic acid in 1000. These numbers correspond very closely with those resulting from my examinations of the air on board the *Doris*, as will be seen by a glance at the accompanying table.

The large amount of carbonic acid existing always in the air on board ship must be injurious to the health of our sailors. "For," as Pettenkofer observes, "more oxygen is required and taken into the system during the night than in the day. But here we have a deficiency of oxygen, and hardly a trace of ozone present; and this state of things is

accompanied by the presence of twice or thrice to nearly ten times the normal amount of carbonic acid.

It has been proposed to work an electrical machine occasionally on board ship, to make up the deficiency of ozone in the deeper parts, but it seems to me this might do so merely at the expense of the already greatly reduced supply of oxygen.

All the above experiments taken together, exclusive of those made on the upper deck in the fresh air, give an average of 1·76 volumes of carbonic acid in 1000 volumes of air on board the *Doris*.¹

Experiments showing the amount of carbonic acid found in the air on board H.M.'s ship "Doris."

Date.	No. of volumes of CO ₂ per 1000.	Part of the ship examined, with the attendant circumstances.
1873.		
Feb. 15	2·24	Officers' cabin, wardroom, scuttle in, 3 a.m.
" 17	1·03	Lower deck, midnight.
" 19	3·21	Wardroom, 11 p.m., calm, ship rolling and scuttles in.
Mar. 2	2·4	Cell in fore-cockpit, with a prisoner in, 6 a.m.
" 14	1·3	Sick-bay, ports closed, daytime.
" 15	1·2	Weather side of main deck in screened berth, full of enteric fever cases, ports closed on this side.
" 17	·9	On the upper deck, midnight.
" 18	·8	On the upper deck, midnight.
April 20	1·6	Lower deck, in harbour, scuttles out, midnight.
" 21	1·6	Do., upper part, in harbour, scuttles out, midnight.
" "	1·35	Do., lower part, in harbour, scuttles out, midnight.
" 22	1·7	Lower deck, in harbour, scuttles out, midnight.
" 23	2·05	Wardroom, in harbour, midnight.
" 30	1·5	Lower deck, in harbour, scuttles out, midnight.
" "	1·4	After-cockpit, windsail down, midnight.
May 3	1·7	Fore-cockpit, no windsail, midnight.
" "	1·1	Lower deck, foreward, midnight.
" "	2·6	Officers' cabin, in wardroom, midnight.
" 9	1·3	Wardroom, scuttles out in cabins, daytime.
" "	1·2	Do., scuttles out in cabins, fresh breeze, midnight.
" 11	1·3	Do., scuttles out in cabins, fresh breeze, midnight.

¹ Air containing 1·0 vol. of carbonic acid to 1000 is close and fusty; above this it becomes disagreeable. Air containing less than 0·6 per 1000 volumes is not perceptibly impure to the senses. (*Vide* Parkes, 'Hygiene,' 3rd edition, pp. 119, 120.)