

ART. XXVIII.—*On the Influence of Ripples on the Gas Content of the Artesian Waters of Christchurch.*

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[*Read before the Philosophical Institute of Canterbury, 6th October, 1909.*]

THIS paper may be regarded as a continuation of a paper read before the Institute on the 13th July. The work was undertaken to ascertain the gas content of some of the artesian about Christchurch, and how quickly the content was altered to the normally saturated condition by rippling over obstacles. The wells examined were the Museum well and the well at the fish-hatcheries. At the Museum a series of four boxes was placed so that the water ran from one to the other in open channels. The distances were: From box 1 (into which the water ran direct from the well) to box 2, 3 ft.; box 2 to box 3, 6 ft.; and box 3 to box 4, 5 ft. The gas contents of these were all examined several times, with the following results:—

	Determination.		
	C.c. per Litre at N.P.T.		
	1.	2.	3.
Box No. 1,—			
Nitrogen, argon, &c. ..	18.45	18.65	18.45
Oxygen	3.90	4.60	4.40
Carbon-dioxide	1.00	1.40	1.10
Box No. 2,—			
Nitrogen, argon, &c. ..	18.16	16.84	18.30
Oxygen	5.00	5.80	5.00
Carbon-dioxide	1.20	1.80	1.20
Box No. 3,—			
Nitrogen, argon, &c. ..	17.36	18.26	..
Oxygen	4.94	5.06	..
Carbon-dioxide	1.30	0.06	..
Box No. 4,—			
Nitrogen, argon, &c. ..	17.20	17.82	..
Oxygen	5.20	5.28	..
Carbon-dioxide	1.30	0.76	..
Temperature of well, 12.8 C.			

The means of these are,—

Box No. 1,—		Box No. 3,—	
Nitrogen, argon, &c. ..	18.52	Nitrogen, argon, &c. ..	17.81
Oxygen	4.30	Oxygen	5.00
Carbon-dioxide	1.19	Carbon-dioxide	0.95
Box No. 2,—		Box No. 4,—	
Nitrogen, argon, &c. ..	17.76	Nitrogen, argon, &c. ..	17.51
Oxygen	5.27	Oxygen	5.24
Carbon-dioxide	1.40	Carbon-dioxide	1.03

Throughout this work the CO₂ includes also any that might be given off by bicarbonates in solution on heating.

Tests were made for SH₂ and SO₂, which showed that there was no appreciable quantity of either present.

Gas Content of Water at Fish-hatchery.—The water in the Acclimatisation Society's hatchery boxes was also examined, the top box of the series

being previously examined for radio-activity, and also the bottom being tested.

	Determination.		
	C.c. per Litre at N.P.T.		
	1.	2.	3.
Top box,—			
Nitrogen, argon, &c. ..	16.00	16.85	17.60
Oxygen	5.80	5.22	5.00
Carbon-dioxide	2.18	1.61	1.60
Bottom box,—			
Nitrogen, argon, &c. ..	16.70	15.30	15.95
Oxygen	6.10	5.30	5.65
Carbon-dioxide	1.16	2.30	2.18

Temperature of well, 12.7 C.

The means of these are,—

Top box,—		Bottom box,—	
Nitrogen, argon, &c. ..	16.82	Nitrogen, argon, &c. ..	15.98
Oxygen	5.34	Oxygen	5.68
Carbon-dioxide	1.80	Carbon-dioxide	1.88

As a check, the water of the Avon was examined, and the gas content found as follows:—

	C.c. per Litre at N.P.T.		
Nitrogen, argon, &c.	15.36
Oxygen	7.74
Carbon-dioxide	1.30

Temperature, 11.4 C.

which are just about ordinary saturation values at the temperature.

From the above it appears that the gas content of these wells varies within small limits, as we are of opinion that the different values obtained in the several determinations of the same water are real, and are not to be ascribed to errors. It also appears from the mean values that the effect of rippling is to diminish the nitrogen content and to increase the amount of oxygen; and, whilst the top box of the series at the hatchery contains an excess of nitrogen over river values of 1.4 c.c. per litre, and of oxygen a deficit of 2.4 c.c. per litre, at the bottom box these are altered to nitrogen in excess 0.62, and oxygen in defect 1.06.

As the cause of this part of these experiments was the peculiar mortality to be found amongst trout confined close to a well, the facts regarding this mortality may be briefly restated.

Of trout confined near the Museum well, a very large proportion die within a few days. Of those not dying, few escape what is known as "pop-eye," a disease which manifests itself by a protrusion of the eyeball. This disease has been ascribed by Marsh and Goreham to an excess of gas, chiefly nitrogen, in the water.

Of eggs hatched in the boxes we have examined at the hatchery a considerable proportion die, and the mortality in the egg-state diminishes rapidly over the series of boxes, of which the first and fifth have been examined for gas content. The figures relating to these were given previously.

Blue Swelling.—This disease attacks the young trout in the yolk-sac stage, and, like the three previously mentioned, its effects seem to fall off

rapidly as the young fry are removed farther from the well-pipe. The yolk-sac develops a bluish portion, and an examination of this shows it to be filled with a fluid, and not with a gas.

With regard to the mortality amongst the ova, and the blue swelling, some experiments, which were in progress at the time the previous paper was read, have, with the aid of Mr. Rides, of the fish-hatcheries, just been completed. It will be remembered that of 15,000 eggs put in each pair of five sets of boxes, from box to box of which the water rippled and splashed down, the following were the deaths in the egg stage:—

Box No. 1	..	..	..	..	..	6,675
„ No. 2	..	..	..	..	..	5,232
„ No. 3	..	..	..	..	..	4,650
„ No. 4	..	..	..	..	..	4,713
„ No. 5	..	..	..	..	..	3,252

Thus there hatched in—

Box No. 1	..	..	..	..	..	8,325
„ No. 2	..	..	..	..	..	9,768
„ No. 3	..	..	..	..	..	10,350
„ No. 4	..	..	..	..	..	10,287
„ No. 5	..	..	..	..	..	11,748

and of these numbers the following developed blue swelling:—

Box No. 1	..	..	..	..	..	1,626
„ No. 2	..	..	..	..	..	1,269
„ No. 3	..	..	..	..	..	1,584
„ No. 4	..	..	..	..	..	1,358
„ No. 5	..	..	..	..	..	1,557

or the following percentages of the fry which were born. The gas content of the first and last, and the radium-emanation content of the series, is given along with these:—

Box No.	..	Percentage of Fish developing Blue Swelling.	Gas Content.	Radium Emanation.
Box No. 1	..	19.5	{ Nitrogen, 16.82 Oxygen, 5.34 Carbon-dioxide, 1.80 }	126
„ No. 2	..	13.0	..	111
„ No. 3	..	15.4	..	95
„ No. 4	..	13.0	..	83
„ No. 5	..	13.0	{ Nitrogen, 15.98 Oxygen, 5.68 Carbon-dioxide, 1.88 }	69

The acclimatisation authorities assert that the proportion of blue swelling in the top box to that in the bottom is usually much greater than this, and ascribe its comparatively even distribution over the boxes to the fact that, owing to conditions, eggs likely to develop it died before hatching.

In another series of eight boxes arranged so that the water rippled from box to box, the ratio of blue swelling in box 1 to that in box 8 was 5 to 2. We have no data regarding the gas content or radium-emanation content of this series, but the figures given seem to show that the mortality amongst eggs, the blue swelling, and also the radium-emanation and the nitrogen content, fall off, whilst the amount of oxygen slightly increases.

To throw further light on the first two effects—viz., mortality amongst yearlings, and pop-eye—lots of ten fish were placed in each of the boxes 1, 3, and 4 at the Museum. It was already known that both death and pop-eye occurred in box 2. The result of these experiments was to a certain extent vitiated by the extreme agility with which the fish escaped, even though every care was taken to prevent it. The radium-emanation content was, in the units we have used, as follows:—

Box No. 1	..	..	..	..	..	197
„ No. 2	..	..	..	..	..	179
„ No. 3	..	..	..	..	..	164
„ No. 4	..	..	..	..	..	150

The fish were very kindly supplied to us by the Acclimatisation Society. From the reason given, we are unable to supply any exact data as to numbers, but it is unquestionable that both death and pop-eye occur most readily in the boxes nearest the well. Whilst this is so, of 10 fish put into box No. 4 on the 3rd September, 1 died on the 6th September, 1 on the 14th September, and 1 on the 18th September. We have not recorded a case of pop-eye in box No. 4, though it occurred in box No. 3.

The fish dying in these boxes were submitted to Dr. Chilton for examination; and he found clear evidence in some, though not in all, of gas emboli in the gill-filaments, and on pricking the conjunctiva of a fish with pop-eye, two or three bubbles of gas escaped from behind the eye, and the eye resumed its proper and normal position.

An examination of a pool in the Gardens where large numbers of fish were kept in very close confinement for stripping purposes gave the following gas content:—

	C.c. per Litre.					
Nitrogen	16.95
Oxygen	4.59
Carbon-dioxide	2.16

Temperature, 12.4 C.

Comparing these figures with box 3 at the Museum, in which on several trials a large number of fish died, and in which one case of pop-eye was developed, it will be seen that less than a cubic centimetre per litre of nitrogen divides the two, and about 0.4 of a cubic centimetre of oxygen, and yet the difference is one of life and death. Whilst this is so, the radium-emanation contents are, in box 3, 164, and in the stripping-pool, 80.

An attempt was made to determine the nature of the gas liberated from behind the eye in a fish suffering from pop-eye, by means of a spectroscopic examination of it, but without certain result. It is hoped to decide the point definitely later on.

The whole question is one for biologists and physiologists rather than for physicists; and the problems suggested to them for discussion are these: (1) Is the difference in the amount of nitrogen sufficient to explain the effects, of which there are four separate ones? (2) Are these effects due to an insufficiency of oxygen? or (3) are the gas emboli in the gill-filaments and the gas behind the eye a secondary effect caused by radium emanation, which is, though present in extremely minute quantities, so extraordinarily active a gas as to be possibly capable of producing the effect if the first two questions should be answered in the negative?