potassium, which was freely given at first, seem to have any effect upon the progress of the disease.

Query, had the persistent habit of self-abuse for three years a remote influence in giving rise to the morbid process in the brain?

ART. III.—*Remarks on the Water Supply in Dublin in 1890 and 1894.*^a By WILLIAM ROBERT GRAVES, L.R.C.P.I., L.R.C.S.I.; Pathologist to the City of Dublin Hospital.

IN laying before you the result of my experiments I am influenced by three motives—first, I desire to show that the large increase of pressure in the city mains which has occurred since 1890 simply means an increase of subsoil saturation, and therefore that such increase of pressure must be regarded as a grave danger to the public health; second, I wish to make it evident that the City Engineer is mistaken in his reply to the first report on the water supply, of the Sub-Committee of the Dublin Sanitary Association, in charging the citizens with “individually” causing the large waste of water in the city; and third, I hope that a careful consideration of the results of my experiments will lead to a great reduction in such waste.

In watching the Corporation plumber removing the meter from the water-supply pipe of my house, I noticed that he discovered and repaired a small leak between the meter and the house, which he afterwards described to me as “an old leak.” This leak was a very small one, and the jet of water from it was very fine. I was surprised, therefore, to find that the reading of the Corporation meter differed very seriously from the meter which I had placed on the supply-pipe inside my house. This led me to experiment with pin-hole leaks, and the results not only explain this difference, but force me to the conclusion that, for a given leak, the waste of water is much larger this year (1894) than it was in 1890, and also that the total leakage of water in the city actually exceeds the amount used by the inhabitants.

From Table I., set out in the Appendix, it will be seen that the lowest pressures of 1894 far exceed the highest pressures of 1890. I give two sets of experiments conducted with holes—one, one-sixteenth of an inch, and the other, one millimeter ($\cdot 04$ of an

^a Read before the Dublin Sanitary Association, on Thursday, June 7, 1894.

inch) in diameter. The latter I call a pin-hole leak. The pressures recorded were taken from the same pipe, and the gauge was placed close to the leak. The pressure was reduced by turning on a tap or taps beyond the leak, thus simulating the reduction of pressure which occurs during the daytime while the citizens are using the water. As a matter of fact, it is immaterial how the pressure is controlled, as the leakage is the same whether the control is before or beyond the leak. The velocity of the flow in the pipes in Dublin never becomes so great as to diminish the flow from a small leak. In the first place, I must explain that in order to correctly estimate the leakage from any given hole in 24 hours, it is necessary to find out the varying pressures to which it will be subjected. Now it happens that I have got pressure tracings, which were taken continuously day and night for two weeks during the year 1890. A similar continuous observation for two weeks of the pressure now prevailing has enabled me to contrast the leakage from similar holes in 1890 and in 1894. The results are contained in the tables given in the Appendix. (I have noted the pressures at different parts of the city, both in the daytime and at night; as might be expected, these pressures vary considerably, but each main tells its own story of leakage and use.) From the tables given in the Appendix it will be seen that, omitting fractions, the average daily pressure in 1894 is 91 lbs. per square inch, as against 48 lbs. in 1890. The pin-hole leaked 434 gallons daily in 1894, against 301 gallons in 1890—or one-third more. The $\frac{1}{16}$ th of an inch hole (a very small hole) leaked 1,284 gallons daily in 1894, against 800 gallons in 1890—or more than half as much again; while larger holes leak probably double the amount in 1894 that they did in 1890.

It is not necessary, in this paper, to enter more fully into details of leakage at the increased pressure. From the experiments made I have all the materials that I need to make my deductions.

Now why has the pressure increased to this extent since the year 1890? In 1890 no one thought of the possibility of our water supply running short. Last year came the great drought, and the oldest inhabitant cannot remember such a vigorous checking of waste by the Inspectors as has been carried on since the month of August, 1893. This great checking of waste, together with the contraction of the use of water on the part of the citizens, has had the effect of alarmingly increasing the pressure and there-

fore of greatly increasing the waste of water into the ground (*vide* tables given in the Appendix).^a

Why is the pressure in the city not controlled in 1894? The pressure has probably been allowed to rise in order the better to supply Drumcondra, Clontarf, and Kilmainham, and districts beyond, which take their supplies from the city mains at places remote from the city inlet at Leeson-street Bridge. The waste and use in the city mains so reduces the pressure that by the time the water reaches these districts, and the districts supplied by the Vartry beyond them, it is impossible to give them an adequate supply unless the pressure in the city is kept at a very high point. This arrangement is a manifest injustice to the Dublin citizen, who has probably more water forced through his fittings or into the subsoil by the high pressure than would supply these outlying districts twice over. Moreover, these districts are not supplied by meter. Thus an undue pressure has to be kept up in Dublin in order that these unmetered suburbs may get a sufficient supply which they are at liberty to squander as they please.^b Drumcondra, Clontarf, and Kilmainham should derive their supply direct from Leeson-street Bridge and should pay for it by meter. This would give the householders in these suburbs a plentiful supply of water at all times, and by making the authorities responsible for the amount of water which was used would soon make them check the underground waste, which forms almost the whole of the waste at present in the suburbs. I know of one suburb in which the waste has been reduced by 50 per cent. within the last year, as proved by the amount passing at night (nearly all of it being underground). If Kilmainham, Drumcondra, and Clontarf were supplied from Leeson-street Bridge, not only would the suburban householders have an abundant supply of water at a good pressure, but the city would then be very well under control, and the pressure need never be allowed to rise above 60 lbs.

It is evident that, the pressure being uncontrolled and the

^a The City Engineer states that in 1893 he succeeded in reducing the amount of water flowing over Callow Hill Weir from twenty million to fourteen and a half million gallons daily. This may have been true of 1893, when the water supply practically failed. It would be interesting to know what is the daily amount now passing over the weir.

^b The average pressures at Clontarf inlet—i.e., at Ballybough Bridge—are, mid-night, 94 lbs., mid-day, 50 lbs.; and I have records of the pressures a mile distant from the inlet which are of great interest.

same amount of water passing into the city, every gallon that the Inspectors succeed in preventing the citizens from running through their system of pipes will cause an increase of pressure, and, as may be seen from the tables given in the Appendix, such increase of pressure will cause an increased leakage into the sub-soil. Fortunately, however, this is to a certain extent modified by the fact that the high pressure prevailing at night (over 100 lbs. on the square inch) overcomes the equilibrium of many of the ball cocks, and thus sets a large number of cistern taps running—the ball-cocks, which are on a balance, as it were, at 100 lbs., becoming automatic controllers of pressure, which is thus unable to rise above 105 lbs. The unfortunate citizen, however, is “between the devil and the deep sea,” for the moment the pressure rises to 90 or 100 lbs. his ball-cocks will probably begin to leak, and while he sleeps, blissfully unconscious of what is going on, the night Inspector may be listening to his street cock, and, hearing the noise, will promptly report him for wasting water. (A ball-cock on one of my cisterns is as good as a pressure gauge. I have had it under observation for more than a month, and it starts to run at 95 lbs., and will run until steadied by the hand at the higher pressure.) Later on, the day Inspector fails to find any water running, and the householder is set down by the City Engineer as one of those who “deliberately, or through carelessness or neglect” leaves his tap running. But his trouble is not at an end here, for this uncalled-for and quite unneeded high pressure injures his lead pipes, which sometimes swell out, tear their holdfasts out of the wall, and finally lengthen, sag down, and in many cases burst.

The high pressure thus entails a large outlay on the part of the householder for the repair of his pipes and fittings, for every alteration of the shape of the pipe is liable to cause cracks in its smooth wall, and, in the minute cracks so formed, a “pit” soon occurs.^a The City Engineer apparently builds his firm belief in the integrity of his water mains on the reports of his “night Inspectors,” who have “found no defect underground.” Personally, having examined many of these pipes during the carrying

^a A “pit” in a lead pipe is a loss of substance in the wall of the pipe, which, once it has started, goes on eating its way through the pipe until it perforates it. Pitting in the hot water pipes is not to be confounded with pitting in the cold pipes; for in the hot water pipes the sudden alternations of heat and cold, with the constant circulation of water in the pipes, combined with probable galvanic action between the copper boiler and the lead, renders the life of the lead pipe a very short one.

out of repairs, I should be inclined, from the corroded appearance of the main at the ferrules (the rings or caps of metal which make the joint between the house service pipe and the main), to say that there were not many of them staunch, and it certainly would be little short of a miracle if they were, when it is understood that the majority of the holes in the mains for these connections have been "jumped." A "jumped hole" is thus made:—A circle is cut with a diamond-pointed tool and a hammer, and when there is need for hurry, after the cut has been made to a certain depth, the circular piece is knocked in or "jumped" by a heavy blow. As a natural consequence the resulting hole is jagged and uneven, and the tap cuts but a poor thread. A dab of white lead makes a kind of joint for a time, but soon gets driven out by the force of the water, and a minute leak, or perhaps one as big as a pin-hole, or even larger, occurs; sometimes even the ferrule itself is driven out of the main. This blowing out of the ferrule was, and probably is, a common occurrence in the old mains, in which not only was the hole "jumped," but the ferrule was simply driven home without any attempt being made to cut a thread in the hole. Such accidents were, in many instances, repaired by driving in a wooden plug. Evidence against the efficiency of "jumped" holes is not lacking. A large proportion of them are not staunch, and they should be for the future forbidden. As there are probably not less than thirty thousand of these joints, a large proportion of which may have been "jumped," it is not hard to understand why the leakage in Dublin may actually exceed the real use. That it does so is proved by the fact that the uncontrolled head of water never produces a pressure exceeding 105 lbs., while if there were no leakage the pressure would be 133 lbs. The difference in level between the pressure gauge fixed in my house and the Stillorgan reservoir would represent 133 lbs. if there was no leakage or use of water. The pressure at night, when no water is being used by the citizens, is not 133 lbs. but 105 lbs., a reduction of 28 lbs., which must be mainly due to leakage. By day, during the hours of maximum use by the citizens, this pressure of 105 lbs. is further reduced to 80 lbs., a reduction of only 25 lbs.; thus the leakage is actually in excess of the real use.

In a neighbouring township (where the pressure was kept within moderate limits during the day) the amount of water passing through the pipes at night was found to exceed the amount passing in the day during a similar interval. This proved that the leakage

at the higher pressure during the night exceeded the real use plus the leakage at the lower pressure during the day. The following questions naturally occur :—

If the pressure of 1890 sufficed, why was the water not cut off as the pressure rose in 1894?

Why, in fact, is the pressure not controlled so as not to exceed say 60 lbs. either by day or night? save in case of fire.* This would be a good working pressure. In the event of fire it is obvious that to give a good pressure the mains must be made staunch, and that the house service pipes must not be allowed, through leakage, to lower the pressure.

The worst fears of the Typhoid Fever Inquiry Committee, and of the Dublin Sanitary Association, as to subsoil saturation, are realised in a very important district within a few minutes' walk of my house, in the very best and most important part of the city. The subsoil saturation is only too evident. Some of the houses in the district have had to fix permanent drains, connecting them with the main sewers, in order to get rid of the constant filling of their cellars by water trickling through from the surrounding soil.

What advantage is gained by so energetically checking waste in private houses if the only result is that of every gallon saved from the service pipes a large proportion is pushed by the uncontrolled high pressure into the subsoil?

Why are Clontarf, Kilmainham, and Drumcondra not served with a metered supply from Leeson-street bridge? Clontarf and Drumcondra could have a common main.

How long will the citizens submit to have their lead pipes destroyed by the abnormally high pressure which is, in many instances, producing the very leakage for which they are held responsible?

It must be remembered that should it be thought expedient to allow a permanent high pressure to prevail in the city, the mains will have to be made staunch at once, and the house service pipes will in future have to be made strong enough to bear the high pressure without yielding.

By all means let the vigorous checking of waste be kept up, but there should be a weekly statement published of the amount of water sent over Callow Hill Weir. Let the householder, however,

* It was reported that on the turning on of the pressure for Arnett's fire one of the mains burst, and so the water supply became inadequate.

be protected from an undue pressure during the hours that he requires but little water, especially as it is now proved that such increase of pressure simply means increase of waste.

TABLE I.

	1890	1894
Six hours, 9 a.m. to 3 p.m. . .	35 lbs. average	80 lbs. average
Eight hours, 3 p.m. to 11 p.m. . .	50 " "	90 " "
Six hours, 11 p.m. to 5 a.m. . .	60 " "	105 " "
Four hours, 5 a.m. to 9 a.m. . .	50 " "	90 " "
Average daily pressure .	48½ lbs.	91¼ lbs.

TABLE II.

Pressure per sq. inch	No. of Gallons per hour run by a pin-hole leak 0·04 inch diameter	No. of Gallons per hour run by a hole 1-16th of an inch in diameter
5 lbs.	4·25	10·36
10 "	6·00	14·50
20 "	8·25	19·90
30 "	10·00	24·45
35 "	10·75	26·60
40 "	11·25	29·25
50 "	12·75	34·00
60 "	14·00	38·75
70 "	15·35	43·50
80 "	16·60	48·25
90 "	17·90	52·90
100 "	19·25	57·65
105 "	20·00	60·00

TABLE III.—*Contrasting leakage from $\frac{1}{8}$ th inch hole in 1890 and in 1894.*

—	1890			1894		
	Pressure	Gallons per hour	Total	Pressure	Gallons per hour	Total
Six hours, 9 a.m. to 3 p.m.	35 lbs.	26·6	159·6	80 lbs.	48·25	289·5
Eight hours, 3 p.m. to 11 p.m.	50 „	34·0	272·0	90 „	52·9	423·2
Six hours, 11 p.m. to 5 a.m.	60 „	38·75	232·5	105 „	60·0	360·0
Four hours, 5 a.m. to 9 a.m.	50 „	34·0	136·0	90 „	52·9	211·6
24 hours			800·1			1,284·3

Four hundred and eighty-four gallons daily, or 176,733 gallons annually, more leaked in 1894 than in 1890 from hole $\frac{1}{8}$ th inch in diameter.

TABLE IV.—*Contrasting leakage from 1 millimeter hole in 1890 and in 1894.*

—	1890			1894		
	Pressure	Gallons per hour	Total	Pressure	Gallons per hour	Total
Six hours, 9 a.m. to 3 p.m.	35 lbs.	10·75	64·5	80 lbs.	16·6	99·6
Eight hours, 3 p.m. to 11 p.m.	50 „	12·75	102·0	90 „	17·9	143·2
Six hours, 11 p.m. to 5 a.m.	60 „	14·0	84·0	105 „	20·0	120·0
Four hours, 5 a.m. to 9 a.m.	50 „	12·75	51·0	90 „	17·9	71·6
24 hours .			301·5			434·4

One hundred and thirty-two gallons daily, or 48,508 gallons annually, more leaked in 1894 than in 1890 from hole 1 millimeter in diameter (pin hole).