

CHAPTER XXXV.

ON THE PROPAGATION OF EPIDEMICS BY POTABLE WATER.

THE researches of M. Chaveau,* confirmed by Dr. J. S. Burdon Sanderson, F.R.S.,† prove incontestably that the virus of small-pox, sheep-pox, and glanders resides in the finer suspended matter, *granulations élémentaires*, and not in the serous fluid of suspension; when these organic granules were removed, the fluid, though containing soluble, unorganized materials, was perfectly incapable of communicating the disease to the animal inoculated. The minute organized granules are the poisonous agents, that after finding a suitable *nidus* in the bodies of animals, then multiply spores, and produce the specific disturbance of the normal vital functions characterizing diseases of the zymotic class. The germs have as yet not been isolated or individually recognized, but no doubt remains that the greatest dilution of a virus, such as vaccine matter, has no effect on the virulence of the disease or result produced, though the inoculation becomes uncertain, as the operator may fail to convey to the wound a single germ. Similar experiments upon the virus of small-pox, of sheep-pox, and of glanders led to similar results.

It is a fact that zymotic germs containing the poison of cholera and typhoid or enteric fever are communicated occasionally from individual to individual, through the air, but the larger majority of cases are due to the use of drinking water containing, disgusting as it may appear, the dis-

* 'Comptes Rendus de l'Académie des Sciences,' tome lxxvi., 1868, pp. 289, 317, and 359.

† 'Twelfth Report of the Medical Officer of the Privy Council,' 1869.

charges of patients suffering from these diseases. The history of the *cholera* visitation in London throws much light on the facility with which a disease may be propagated by water.

The respective condition of water supply and cholera mortality were as follows:—

| | Character of water supply. | Total mortality from cholera. | Mortality from cholera per 10,000. | |
|-------------|----------------------------|-------------------------------|------------------------------------|------|
| Epidemic of | 1832 | Polluted | 5,275 | 31·4 |
| | 1849 | Very much polluted | 14,137 | 61·8 |
| | 1854 | Less polluted | 10,738 | 42·9 |
| | 1866 | Much less polluted | 5,596 | 18·4 |

In 1832, London was chiefly supplied with water from the *THAMES* and *Lea*, and shallow wells, populations were smaller on the banks of the rivers, and no efficient system of sewerage existed; this, in 1849, had been carried out, and the *THAMES*, *Lea*, and *Ravensbourne* were converted into a perfect organization for the diffusion of sewage into the drinking water for daily consumption by the inhabitants of London, the mortality varied directly with the amount of pollution. Dr. W. Farr, F.R.S., pointed out to the then Registrar-General, that of the metropolitan population supplied by water taken from the *THAMES* at Kew only 8 died in 10,000, while of those supplied from the *THAMES* at Hammersmith 17 died; of those in Belgravia, Chelsea, and Westminster using water taken below Chelsea Hospital 47 died; and in districts drawing their supplies between Hungerford and Waterloo Bridges, where the river was in an exceedingly bad condition, the deaths were 163 to 10,000 inhabitants. In 1854 the *Southwark Company*, supplying Bermondsey, still drew its supplies from Battersea, close to one of the sewers, and the death-rate was greater than before. In Lambeth the rate fell from 1618 to 904, through being partly supplied with water by the *Lambeth Company*, who had moved in the interim their intake to Teddington, beyond the range of

the London sewage; the difference of the rate in the same district being 40 per 10,000 supplied by the *Lambeth*, and 130 per 10,000 supplied by the *Southwark and Vauxhall Company*. This gigantic crucial experiment, performed on half a million of people, conclusively proved, as pointed out by Mr. John Simon, F.R.S., the cause of the great mortality. In the next epidemic period, 1866, both companies supplying the south of London had moved their intake to a purer part of the *THAMES*, and the cholera mortality here was comparatively insignificant. The disease in high development was confined to certain parts of the east of London, within the area of the *East London Waterworks Company*, and further restricted to that portion of their district which they supplied with water they obtained from a polluted portion of the *Lea*, stored unfiltered in uncovered reservoirs at Old Ford, supplied when the filtered water ran short early in July. July 10th, there were no deaths, on July the 31st there were 171 deaths, on August 1st, 170, on which day the Company was warned by the Registrar-General, and the deaths diminished on August 2nd to 155, and declined daily to 8 on September 1st.

The parish of ST. JAMES, WESTMINSTER, occupies 164 statute acres, with a population of rather less than 40,000, which has not varied much between the census of 1831 and 1851. In the cholera visitation of 1832 there were only about 45 deaths; the sanitary condition was improved, and in the epidemics of 1848-9 there were only 3 deaths. In 1850 there were 4 fatal cases, in 1851 and 1852, 1 case in each year. In the last four months of 1853 cholera became again epidemic in London, and 7 deaths in the Great Marlborough Street and Poland Street district. In the following year cholera was present in the spring, but no deaths took place in St. James's until the week ending the 5th of August; in the following week there were 5 deaths, then 12, then 6, then 78, and in the week ending September 9th, no less than 287, after which it declined, the last death being in the week ending October 7th, showing its gradual approach, a lull in its operation, and

then the sudden terrible outburst, outstripping the most energetic efforts to mitigate its effects. The investigations of Dr. Snow show the outbreak was principally confined to the area about the Broad Street pump. That 61 out of 73 persons who first died used the pump water. That the water was used for various purposes. That in the workhouse in the centre of the affected area, where the water was not used, only 5 deaths occurred, while 50 would have been the proportionate death rate. That in a factory using the water, 18 died out of 200 persons employed. That in the Brewery, with 70 men employed, who did not drink the water, none died. That sporadic cases occurred through people sending for the water from a distance. That the mortality diminished in the neighbourhood of other pumps. That out of 14 houses in a street, the 4 that escaped without a death did not use the Broad Street pump; and from these facts Dr. Snow deduced the result, that the outbreak was caused by the dissemination of cholera poison by the contamination of the Broad Street well, by the evacuations of a cholera patient from a neighbouring cesspool.

The district consists of 20 to 30 feet of sand and gravel, of an exceedingly porous nature, and is overlaid by 8 to 12 feet of made ground; pump wells are numerous, sunk down to the London Clay, which supports the water. The sides are built of bricks laid dry, through which the water enters. The arches are turned over with brick, laid in mortar or cement, and covered in with a keystone. Many of these wells, including the Broad Street, can soon be pumped dry. Analysis of the water at the latter well shows so large a quantity of common salt (chlorine, 11.240; soda, 16.861), that it must be derived from the *débris* and refuse accumulated in a densely populated district, and not from the waste water of the neighbourhood, which is supplied by the *Grand Junction Water Company*, who pump the *THAMES* at Kew, which there contains of chlorine, 0.84, and of soda, 0.84. A considerable quantity of nitric acid also occurs, which is believed to be derived from decayed animal matter, an

possibly from pest-field soil. This field corresponded to the present Craven Estate, which was given in 1687 by William, the renowned Earl of Craven, to the poor, to be used as a field, on which to erect pest-houses, in case of the reappearance of the plague. The Earl, who fought under Gustavus Adolphus, and married Elizabeth, daughter of James I. and Queen of Bohemia, lived at Craven House, Drury Lane, throughout the whole of the time of the plague, 1665-6, and died in 1697. The field, which was first hired and afterwards bought by the Earl, became the cemetery for the thousands who died in the 36 pest-houses on it.

In 1734 the ground had become built over, and the charitable trusts were transferred to other lands near Byard's watering place, now Bayswater. The width of the pest-field from Marlborough Row to Dufour Place is 4 chains, its length 8 chains, extending between Craven Chapel and Broad Street. That the public water supply did not conduce to the spread of the disease is proved by part of the district, simultaneously affected, being supplied by the *New River* and *Grand Junction Companies*, and it is exceedingly unlikely both companies should have their supplies polluted, though indirectly the mode of supply conduced towards the outbreak, the water being stored in unwholesome and contaminated cisterns and water-butts, causing the people to have recourse to the pump, which yielded sparkling and apparently pure water.

WINDMILL SQUARE, SHOREDITCH.—In 1848-9 this intense outburst was fortunately limited to 5 houses, inhabited by 22 persons, half of whom died in a few days, the details of which are recorded by the late Dr. Gavin.* The water supply was from a well 18 feet deep, which, losing its water through the formation of a sewer, was deepened another 6 feet, and an unfailling supply obtained. The overflow of the cesspools was carried to a pit dug in the centre of the small square,

* Appendix B. 'Report to General Board of Health on Epidemic Cholera,' 1848-9.

and percolation from this made its way into the well, with the fatal results recorded.

The direct relation of cholera to drinking water is remarkably shown in a case given by Snellen at Utrecht, and a case given by Dr. Ballot, of Rotterdam; those who drank the waters of the "Polders" (reclaimed lands) died at the rate 17·7 per 1000; those who drank the well waters 16·8 per 1000; those who drank river water 11·9 per 1000; those who drank rain-water filtered 5·3 per 1000. The City of Amsterdam, supplied by an aqueduct from rain falling on downs near Haarlem, only lost 4 per 1000. In Rotterdam the mortality fell one-half on pure water being supplied.

The cholera outbreak at MERTHYR TYDVIL in 1849 was due to atmospheric infection; the town was expanding, and undrained and unpaved, and ashes and refuse were thrown in front of the houses, and then blown in all directions. To dry ash-pits at Liverpool, often placed in the houses, was due the cholera outbreak of 1866, and to a similar origin was the cholera outburst in 1867 at Zurich, which was traced by Dr. A. Fick, then Professor of Physiology in Zurich, to a child brought from Rome, where cholera was epidemic. These facts show the necessity of preventing the distribution of dry sewage matters in the atmosphere.

The remarkable immunity from cholera, in affected districts, has been shown by the late Sir William Lawrence, F.R.S., Her Majesty's Sergeant-surgeon, who stated that prior to the year 1825, "Bethlem Hospital" and the "House of Occupation," in St. George's Parish, Southwark, were supplied by the *Lambeth Waterworks Company*, but the water leaving a muddy sediment, an artesian boring for water was made 220 feet deep. Not a single case of cholera occurred in 1832, 1849, or 1854, though the neighbourhood suffered severely.

The inhabitants of MANCHESTER and Salford were supplied with polluted water from the *Irwell* and from shallow wells previous to 1851. In the outbreak of cholera in 1832 there were 890 deaths, in that of 1849, 1115 deaths, while

in 1854, with an improved water supply, notwithstanding the increased population, 50, and in 1866, 88 deaths, or $\frac{1}{16}$ th of the previous amount.

In WIGAN, prior to 1866, the only water supply was derived from polluted shallow wells, and in 1849 cholera killed 348 persons. In the 1866 epidemic only 58 died, though the drainage was very imperfect.

SOUTHAMPTON.—The outbreak of cholera in June 1866 is ascribed by Dr. E. A. Parkes, F.R.S., Professor of Hygiene to the Military Hospital at Netley, to choleraic patients arriving in the Peninsula and Oriental steamship "Poonah" from Alexandria, caused by cholera-poisoned water in a tank opened on the voyage, the source of which is unknown. The sick men were brought on shore at a time when the water supply was deficient, and the drainage of the western part of the town, usually raised by pumping into the eastern portion, and carried to the outfall, was stagnant, to allow the cleansing of the sewers. In the beginning of July the steam pump, working night and day, recommenced work, and the air became charged not only with overpowering effluvia, but with minute particles of sewage. These invisible globules were carried to the clean, airy houses in the neighbourhood of the pumping station, and an outbreak commenced that carried off 107 persons. On the 18th of July an iron culvert was substituted for the open channel, and the outbreak at once declined.

Diarrhoea.—Dr. Farr states that this is a common name for a symptom—loss of serous fluids to the blood—produced by various causes, and probably covers diseases as distinct as those confounded under the name of "fever" until separated by the sagacity of Dr. Jenner. The severe diarrhoea, which has been very fatal to children since 1846, Dr. Farr regards as a form of cholera. At Croydon, in 1854, Dr. Carpenter showed the presence of suspended sewage in the drinking water produces choleraic symptoms. Suspended vegetable matter in water will produce diarrhoea. This was

especially found to be the case in the late American Civil War, after drinking surface and ditch water.

Sulphate of lime and magnesium also produce the same effect, especially upon strangers. This has been found in the selenitic water of Paris, and was especially investigated by Parent-Duchâtelet at the Prison of St. Lazare. Similar effects are produced by the presence of nitrate of lime and by brackish waters, whether from salts in the ground or from the infiltration of air water, and by the absorption of sulphuretted hydrogen and other sewer gases by the water in tanks and cisterns.

Dysentery.—Dr. Parkes believes the causes that lead to this disease are suspended animal organic matter, earthy matters, calcium, and magnesium, sulphates and chlorides, calcium and ammonium, nitrates, large quantities of sodium and magnesium, and chloride in solution. Several of the old army surgeons knew of this cause. Champouillon records a cure where two regiments used the impure water from the Canal de l'Oureq, near Paris; one regiment mixed the water with red wine, the other with brandy. The regiment that mixed the water with red wine or coffee, the tannin of which united with the organic matter, had no dysentery; the regiment using brandy, which precipitated the organic matter against the sides of the vessel, where it putrefied, suffered from dysentery, which was at once stopped by the substitution of red wine for brandy.

The Rivers Pollution Commission gives a table of the mortality from cholera in the four visitations, and the average mortality from diarrhoea (see p. 584).

Typhoid fever.—Is endemic in this country, and annually carries off 15,000 persons in England and Wales alone, due in the larger number of instances to the consumption of water polluted by sewage, if not by typhoid sewage, by the individual attacked, its conveyance from infected to healthy

| | Nature of water supply. | Organic element in 100,000 parts. | Total hardness in 100,000 parts. | Population in 1871. | Cholera per 10,000. | | | Diarrhoea per 10,000. | All causes per 1000. |
|------------|-------------------------------|-----------------------------------|----------------------------------|---------------------|---------------------|---------|---------|-----------------------|----------------------|
| | | | | | 1832. | 1848-9. | 1853-4. | | |
| Bath | Polluted springs | .161 to .350 | 16.3 to 31.3 | 52,557 | .. | 12.89 | 0.15 | 8.22 | 22.2 |
| Brakenhead | Deep wells | .062 - .079 | 5.7 - 9.9 | 65,971 | .. | 24.32 | 12.70 | 12.42 | 24.0 |
| Birmingham | { Shallow and deep wells .. } | .124 - .667 | 12.6 - 127.1 | 343,787 | .. | 1.67 | .47 | 20.03 | 24.3 |
| Bradford | Shallow wells.. | .204 - .661 | 6.4 - 7.1 | 145,831 | .. | 23.41 | 1.86 | 13.24 | 26.0 |
| Brighton | Deep wells .. | .057 - .066 | 21.2 - 21.5 | 90,011 | .. | 29.59 | 5.80 | 12.26 | 22.6 |
| Bristol | Surface wells .. | .177 | 24.5 | 182,552 | 52.44 | 80.32 | 11.69 | 9.96 | 23.9 |
| Cardiff | Upland waters | .243 | 20.0 | 39,536 | .. | 85.18 | 48.40 | 7.63 | 21.3 |
| Carlisle | Deep wells .. | .204 | 29.3 | 13,765 | 132.46 | 12.27 | 5.05 | 9.91 | 24.1 |
| Croydon | Deep wells .. | .047 | 22.0 | 71,319 | .. | 29.48 | 28.22 | 9.45 | 19.9 |
| Exeter | Surface wells .. | .243 | 7.7 | 31,652 | 123.05 | 13.40 | 3.05 | 10.12 | 25.5 |
| Hull | Deep wells .. | .061 | 25.4 | 121,892 | 104.93 | .. | .. | .. | 25.2 |
| Leeds | Upland waters | .283 | 8.3 | 259,212 | 56.89 | 122.25 | 4.26 | 19.78 | 28.5 |
| Liverpool | { Upland and deep wells .. } | .004 to .109 | 6.2 to 14.9 | 493,405 | 92.20 | 128.77 | 31.35 | 19.16 | 34.0 |
| London | Surface wells .. | .021 - .765 | 15.5 - 32.1 | 3,254,200 | 87.09 | 59.84 | 45.46 | 10.49 | 20.6 |
| Lynn | Surface wells .. | .218 | 16.9 | 16,562 | 36.65 | .. | .60 | 6.21 | 22.8 |
| Maryport | Upland waters | .251 | 3.4 | 15,719 | .. | .. | .. | .. | .. |

persons being similar to the conditions under which Asiatic cholera is propagated.

Riecke* gives a *résumé* of the progress of knowledge on this subject. In 1760 the use of impure water was in part attributed as the cause of the "schlien-feber," at Göttingen, in 1822; a similar cause was assigned by Walz to the outbreak of "typhus" (typhoid) at Saarlouis, in Rhenish Prussia; in 1843 Müller discovered that 129 cases of "typhus abdominalis" (typhoid), and 21 deaths occurring in the garrison at Mayence, were due to polluted water supply. In 1848 Dr. E. A. W. Richter proved a similar cause for an outburst at a school in Vienna.

Dr. Parkes † continues this list: in 1852 Dr. Austin Flint published the particulars of a similar outbreak in North Boston (Erie, U.S.) in 1843. In 1852-3 a severe outbreak of typhoid at Croydon was shown to be due in great part to pollution of drinking water from cesspools. In 1856 Dr. Routh published a similar case at Hastings, and, in 1857, Dr. Budd two other well-attested cases. In 1860 an outbreak due to this cause occurred at the Convent of Sisters of Charity, Munich; out of 120 persons 31 were attacked, and 24 died. The fever disappeared with change of water supply.

LONDON.—Surgeon Major A. C. C. Renzy gives an instructive account of the extinction of typhoid fever in the Millbank Prison by the disuse of *THAMES* water, in the 'Lancet' of Jan. 8th, 1872. The prison was opened in 1816, and had a bad reputation for unhealthiness; the cholera epidemics of 1833, 1847, and 1853-5 were very fatal, and phthisis and typhoid were ever present up to August, 1854. On the 10th of that month the water supply was changed from the *THAMES*, as it flows past the institution, purified by filtration, to the artesian well in Trafalgar Square. Six days after, cholera, which was the epidemic in the prison, ceased, and the typhoid death-rate, from 1845 to 1854, of 5.7 per

* 'Der Kriegs und Friedens-Typhus.' Nordhausen, 1850.

† 'Hygiene,' p. 45, 5th ed.

thousand was reduced to three deaths from typhoid between 1855 and 1872, all of which were contracted before the patients were imprisoned. Practically typhoid disappeared with the disuse of *THAMES* water, all other sanitary conditions remaining the same.

TERLING, ESSEX.—In the autumn of 1867, out of 900 inhabitants, 300 were attacked with typhoid fever, and 41 died. The village is built on the sloping banks of the *Ter*, an affluent of the River *BLACKWATER*. Dr. Thorne Thorne, of the Local Government Department, reports that the subsoil is clay overlaid by sand and gravel; previous to the epidemic was a drought, followed by a heavy rainfall and rise of water in the wells, which washed out a mass of polluted matter, which had accumulated in the loose and porous soil. Two wells, that were not so circumstanced as to be affected by those conditions, supplied two groups of cottages that were not affected by the epidemic fever.

CHICHESTER in 1865 was severely visited by typhoid and low fever, and was inspected by Dr. Edward C. Seaton, of the Medical Department of the Privy Council. It is built on 20 feet of gravel, resting on impermeable clay. The gravel receives the drainage in shallow holes, or cesspools, and the water supply is taken from deeper holes, or wells in the same material; in some cases where fevers had occurred these were only within 3 feet of each other. The greatest contamination took place during droughts and after heavy floods, washing sewage into the wells.

SALISBURY.—From 1844-52 the annual mortality from typhoid was 7.50 per 1000 inhabitants, supplied with water from shallow wells, with water standing 2 to 3 feet from the surface, close to cesspits, often overflowing. In 1853 public waterworks and drainage works were commenced, and were completed in 1856; the water was obtained from a well 68 feet deep in the chalk, connected with a tunnel 70 feet long, yielding 46 gallons per head per day; these works reduced the death-rate from typhoid to 1.75 per 1000 for the eight years, 1857-64.

CONGLETON.—Sporadic cases of typhoid fever occurred in the village prior to 1866, when a violent outbreak took place, investigated by Dr. Buchanan, who states that out of 1150 inhabitants, 150 were attacked and 14 fatally, of which outburst a badly-polluted shallow well was the focus, 15 feet in depth, and containing, according to Dr. Miller's analysis, 15,145 parts per 10,000 of private sewage contamination.

PAGE GREEN, TOTTENHAM.—In 1864 and 1865 a severe outbreak of typhoid fever affected 100 persons, and was investigated by Dr. Seaton, of the Medical Department of the Privy Council, who found it to be due to the use of surface-water from shallow wells, and in preference to the hard water supplied by the Local Board.

GUILDFORD.—In September 1867 sporadic typhoid fever became epidemic, 150 cases occurring in a fortnight; of the 1675 houses then in Guildford, only 928 were supplied from the public waterworks, fed by two wells in the chalk, 20 feet deep, situated at the lowest part of the town; an old well from which the water is raised by water power, and a new well, from which water was distributed to the higher parts of the town by pumping engine power. Of the remaining 747 houses the supply is obtained from private wells, or from the River *Wey*. Ten days before the outbreak 330 houses had exceptionally received their water from a service reservoir, which had been filled from the new well sunk in the lowest part of the town, close to several sewers, the brickwork of which was defective, and allowed percolation into the well.

The water-line in the chalk under the town is stated by Dr. Buchanan to be very constant; in the higher part it is considerably below the surface, and cesspools sunk into it are dry and inoffensive; but the lower part of the town is water-logged, and powerful springs flow into the river. The polluted well has since been abandoned, and another sunk on an island in the *Wey*, out of reach of leakage.

SOUTHAMPTON.—Dr. E. A. Parkes, F.R.S., Professor of Military Hygiene in the Army Medical School at Netley,

traces the origin of an outbreak of typhoid fever to the impregnation of drinking water with contamination of sewage, probably of typhoid sewage.

CLIFTON, BRISTOL.—In the autumn of 1847 an outbreak of typhoid fever occurred, which was the subject of the most careful investigation by Dr. William Budd, F.R.S., of Bristol, whose painstaking and persevering research has in a great degree contributed to establish accurate knowledge of the propagation of typhoid fever through the agency of air and water. The outbreak took place in a crescent, called Richmond Terrace, of 34 houses, of which 13 were affected, drawing their water supply from a pump tainted with sewage. The inhabitants of the houses not so supplied were not affected.

COWBRIDGE, S. WALES.—A violent outbreak of typhoid fever occurred here, affecting a large number; 140 persons attended two public balls, held in the chief inn, in November 1853, and of them 8 died; this was found by Dr. Budd to be due to sewage poison in the well from which the drinking water was taken, which had received typhoid poison from a typhoid patient who was staying in the house immediately before the ball. The sanitary defect was soon after discovered and remedied.

WINTERTON, LINCOLNSHIRE.—This market town is well situated on a gentle slope, draining north into the *HUMBER*, and is built on porous oolitic limestone, and enjoys an excellent system of drainage, but has had a prevalence of typhoid fever for some years; in 1867 Dr. Thorne Thorne inspected the place for the Local Government Board, and found all the houses affected drew their water supply from polluted wells.

WICKEN BONANT, ESSEX.—An outbreak of typhoid commenced here on July 25, 1869, which attacked during the autumn 45 persons, and carried off four. The causes were carefully investigated by Dr. Buchanan, for the Medical Department of the Privy Council, aided by Mr. W. H. Penning, of the Geological Survey. The village numbers 40

houses, with 206 inhabitants. It is situated in a valley cut through the Boulder Clay, and scooped out of the gravel beneath, in the channel of a brook running through the village from west to east, the rain-water resting directly on the Chalk. The Gravel is 20 feet thick, and has an irregular base of plastic impervious Clay, which prevents the downward percolation of the drainage received by the Gravels, which flowing through them to the lower part of the valley, is there partly intercepted by the parish well, 250 yards from the point where sewage is discharged. In May, water was flowing in the brook, and there had been heavy rain; in June the whole of the underground water was falling; in July the brook was dry, and water absorbed by the gravel passed directly to the well, 35 yards distant, receiving unchanged specific typhoid poison, which affected no less than 46 per cent. of all the persons that used this well for their water supply.

The Royal Commissioners, commenting on these examples, said, that the existence of specific poisons producing cholera and typhoid fever cannot be denied, disseminated in such fine particles as to be able to pass through ordinary sand and domestic filters, and to be carried by the air, in the form of dust, or in the spray of liquids. They further consider that, when the poison is concentrated, the disease appears suddenly, the period of incubation being short, and the number of individuals attacked large, while, with a very attenuated poison, only those who are very susceptible will be infected, and that even concentrated poison may fail to affect persons with extraordinary powers of resistance; such as that conferred, in typhoid fever, by a previous attack of the disease. Boiling the infected water for half an hour is a probable means of destroying its power of communicating these diseases.

The following conclusions are drawn from these statistics. That the extinction of typhoid and other similar diseases is within the range of practicability; that the extinction of one class of zymotic disease is not necessarily followed by

another; that since some of the ablest physicians in London failed for many years to detect the true cause of the unhealthiness of Millbank Prison, and assigned causes for it which later experience has found to be unconnected with it, the probability is that a similar error is frequently made elsewhere, and that the prevalence of some zymotic diseases is ascribed to locality, malaria, heat, cold, visitations of temperature, moral depression, and other intangible influences, which would be entirely removed by the general disuse of impure water.

CATERHAM AND REDHILL.—An outbreak of typhoid fever occurred simultaneously at these two towns, followed in a few days by cases at Earlswood, Bletchingley, and Nutfield, in all reaching 196 cases in a fortnight, at villages 3 to 10 miles apart. The infected district is supplied by the *Caterham Waterworks Company*, drained from wells in the chalk 500 feet deep, sunk at the southern extremity of the high-lying ground which bounds the Caterham Valley to the west. In the latter part of 1878 and the beginning of 1879, an adit-level, 6 feet by 4 feet, was driven 90 feet from the old well, at a depth of 455 feet from the surface, to connect a new borehole, by the Diamond Boring Company. Dr. Thorne Thorne, who investigated the cause for the Local Government Board, finding that none of the 1400 houses not using the Company's water in the infected district were affected, examined the Waterworks, traced the initiation of the epidemic to the pollution of the water in the adit by a man employed there from the 5th of January, who was actually suffering from enteric fever, and who was obliged to leave work on the 20th of January from the severity of the attack, and on the 2nd of February the epidemic broke out, causing 21 deaths.

The Rivers Pollution Commissioners tabulate the results given in the 9th Report of the Medical Officer of the Privy Council, 1866, p. 35, showing the improvements of public health which result from proper works of drainage and water supply.

Twenty-four towns are enumerated, varying in 1861 in population from 160,714 at Bristol, to 3840 at Ashby; the improvement works were carried out between 1843 and 1857. The improvements reduced the death-rate per 10,000 by 70 at Merthyr, by 116 at Cardiff, by 102 at Newport, by 47 at Croydon, and 61 at Macclesfield; by 41 at Brynmawr, giving for the 6 towns (25 per cent. of the towns improved) an average reduction of death-rate of 73 per 10,000, or 7 per 1000. Examining the statistics to see where the gain takes place, it is noticeable that all these 6 towns had a typhoid fever death-rate of over 14 per 10,000, reaching 23·5 at Brynmawr, which was reduced to 5·5 (Croydon), and a maximum of 10½ at Brynmawr. In the other 18 towns there is only one instance of a higher fever death-rate, viz., 12¾ at Chelmsford, which town stands in the unenviable position of having a higher death-rate after the works than before. Diarrhoea was reduced by the works from 17½ per 10,000 at Cardiff, to 4½ and 50 per cent. in four of the other six towns. Cholera shows most markedly the good results effected. At Merthyr, in the epidemic 1848-9, the death-rate was 267 per 10,000, 84 in 1854, and only 20 in 1866; at Brynmawr, 100 in 1848-9, and none in the next two visitations.

Goitre is defined by Dr. Aitken* as "a specific affection of the thyroid gland induced by the persistent use of water which has percolated through magnesian limestone rocks, or strata, and containing the soluble salts of lime in solution." He refers to the counties of Yorkshire, Derbyshire, and Nottingham, in all of which there are Magnesian Limestone of Permian age, but he also adds Hampshire and Sussex; in the case of these counties it is not so evident from whence the source of the magnesia is derived.

In England, Professor Lebour† states, it is absent on the alluvial deposits, Glacial Drift bed, and the Tertiaries of the

* 'Science and Practice of Medicine,' p. 658, vol. ii. 6th edition, 1872.

† 'On the Geological Distribution of Endemic Goitre in England,' by Professor G. H. Lebour. Privately printed, 1881.

London and Hampshire basins. Endemic cases occur on the Chalk-with-flints, at Newhaven, in Surrey, Hampshire, and Dorsetshire, and around Beaconsfield, Bucks, but it disappears when the sufferer removes to the latter town itself, which is on the Tertiary. It is present on the Upper Greensand and Gault of Sussex and Kent, and on the Lower Greensand, of Ampthill, Bedfordshire. It occurs sparingly on the Weald Clay, and Hastings Sand at Speldhurst, and the neighbourhood of Tunbridge Wells. It is unknown on the Oolites, except at Helmsley. It is very rare on the Lias, but is present at South Petherton.

In Cheshire, goitre, contracted in the Carboniferous Limestone country, is cured by removal to the New Red Sandstone, according to Dr. Moffat, of Hawarden. But goitre is endemic on the New Red of Wombourne, near Wolverhampton, and Crediton in Devonshire. Professor Lebour points out that it is the Carboniferous Limestone, and not the Magnesian districts, that are the hotbed of goitre, especially at Stoney Middleton and Hawes.

In France,* the distribution of goitre can be traced through the examination made by a medical council, of the men coming up for military service. This evidence was carefully weighed in 1848, by a Commission appointed by the Sardinian Government, and more recently by Dr. de St. Lager, of Lyons, who published, in 1867, a mass of information on the subject, from which it appears that goitre, though frequent on limestone, is not confined to it; that altitude, marshes, and deep valleys have no special influence on it.

In France, the distribution of endemic goitre coincides with the occurrence of metalliferous deposits, especially of iron-pyrites.

Calculous disease, in relation to water supply, has been carefully studied by Dr. Thursfield,† especially in regard to

* 'Etudes sur les Causes du Crétinisme et du Goître Endémique.' 8vo. Paris, 1867.

† 'Report on the Borough of Shrewsbury,' 1877.

the records of Salop Infirmary, where, from 1747 to 1877, out of 118 cases occurring to natives of the town, no less than 81 occurred prior to 1820. About this time the use of very hard well-water, contaminated from passage of the water through the subsoil, was given up, and the *SEVERN* water substituted, the old water-wheel purchased, and the present works constructed in 1827. In 1870 the conduit reservoir was erected, and the disease is still further ameliorated.

From these investigations of Dr. Thursfield, it would appear that, though the well-water was very hard, varying from 30° to 40°, and even reaching 70°, its bad effects would probably have not been experienced had there been no organic pollution.

Dyspepsia.—Dr. Sutherland is quoted by Mr. Simon, in his Second Report to the City of London, as stating the bad effects experienced by the use of the hard Liverpool New Red Sandstone wells. These were probably the wells at Bevington Bush, and elsewhere, that have been long disused, from their being not only excessively hard, but fearfully polluted. The water supplied by the existing Corporation wells is perfectly pure and palatable.

Dr. Parkes states that the use of waters containing large quantities of calcium sulphate or chloride and magnesian salts produces various dyspeptic symptoms, and considers 10° of permanent hardness, and even less, will affect some people; while waters containing 50 grains per gallon, as in the case of a well at Chatham, no one will drink. He refers to the dislike of grooms to give their horses hard water, which makes their coats "rough and staring."

Phthisis.—The Tables given by the Rivers Pollution Commission show an improvement in the death-rate per 1000, due to the execution of sanitary works, of 4½ at Merthyr, of 6 at Cardiff, of 16 at Macclesfield, of 12 at Newport. Examining the returns for the 24 towns, the higher death-rate from phthisis before the improvements was, at Leicester 43½, re-

duced 14 per 10,000; Macclesfield $51\frac{1}{2}$, reduced 16; Warwick 40, reduced $7\frac{1}{3}$; Salisbury, $44\frac{2}{3}$, reduced no less than 22. The phthisis and other pulmonary diseases have carried off before the improvements $53\frac{1}{2}$ per 10,000 persons over 20 years of age, which was reduced to $38\frac{1}{2}$, or a gain of 15 lives per 10,000.

Dr. Buchanan, from his investigation of these towns, having ascertained the fact that the decrease of consumptive death-rate is coincident with the lowering of the surface-waters by improved drainage, made a more detailed examination of the causes leading to consumption in the South-east of England, in which work he was aided by Mr. Whitaker, of the Geological Survey, with the result, that consumptive death-rate is least on pervious soils, and decreases with height above sea-level; that it is less on sloping impervious soils than on flat districts; wetness of soil being the cause of the disease.

An exception to these conditions was noticed in the population living on the low-lying impervious flats on the margin of the coast, which appear to be positively beneficial to consumptive patients, the Isle of Sheppy being a very striking case of this, having the smallest consumptive death-rate of the 58 districts into which the South-east of England is divided. Dover, where a large proportion of the population pass their lives on shingle, is another example of similar conditions; pervious soils, saturated with sea-water, having no ill effects in cases of consumption.

In many tracts of impermeable clays much good might be cheaply done by sinking "dumb wells," to carry off the surface-waters into underlying porous beds.

Malarious Fevers.—The influence of salt marsh-water in producing these fevers and ague has long been noticed in foreign lands, and in our own country in the Bedfordshire and Cambridgeshire Fens, at Tilbury Fort, near Gravesend, and at Sheerness; the well at the latter being highly charged with vegetable *débris*. At Houghton, in Bedfordshire, one

family alone escaped from ague, taking their water supply from a well, instead of from the neighbouring ditches.

The investigations of Professors Pettenkofer and Buhl, of Munich, have long shown a connection between the existence of typhoid fever and a porous soil with a watery subsoil; but, as pointed out by the Rivers Pollution Commission, typhoid epidemics have occurred without this being the case; though there appears to be reason to believe that, if the area of absorption of drinking water answers to these conditions, the polluted matter may be then taken up, and when the water flows underground, chiefly through cracks and fissures, as is the case in the chalk, the strata do not exercise any beneficial oxidizing effect. This is believed to be the cause of the periodic outbreaks of fever in the parish of Croydon; Mr. Baldwin Latham, M. Inst. C.E., having clearly connected the years of excessive death-rate from this cause with an absorption of polluted matter by the intermittent appearance of the springs called the *Bourne*, which, being re-absorbed by the chalk lower down, carry the objectionable elements to the wells in the centre of the old town, which are alone affected. When, through long-continued rains, the lower part of the chalk is charged with water, and the Croydon springs run strongly, they prevent the back-flow of any impure water from the surface. Thus, in the wet years 1859 and 1860, though the *Bourne* in the Caterham Valley had an average discharge of 1500 gallons a minute, it failed to reach the town of Croydon, disappearing in the neighbourhood of Caterham Junction railway station. These were healthy years, because, after artificially abstracting a portion of the lower underground water by pumping, a balance was left overflowing in strong springs at the rate of 3500 gallons a minute.*

When the *Bourne* commences to run after a sudden and copious rainfall, when the springs are comparatively low,

* 'Min. Proc. Inst. C.E.,' vol. xlv. 1876. Disc. on Rainfall, Evaporation, and Percolation.

(as was the case in 1853 and 1866), the water-line under the town is elevated, and an outbreak of enteric fever results.

In an interesting communication made by Mr. Baldwin Latham to the British Association, at York, he states* that it was alleged, by some of the long-established millers on the chalk streams, that they were able to foretell the appearance of rainfall from a sensible increase in the volume of water flowing down the stream before the period of rainfall. He had undertaken a series of observations to investigate the phenomena, and found, in setting up gauges in the *Bourne* flow in the Caterham Valley in the spring of this year (1881), and selecting periods when there was no rain to vitiate the results, that, whenever there was a rapid fall in the barometer, there was a corresponding increase in the volume of water flowing, and, with a rise of the barometer, there was a diminution in the flow. The gaugings of deep wells also confirmed these observations; for where there was a large amount of water in the strata above the water-line, held by capillarity at the period of the year when the wells became sensitive and the flow from the strata was sluggish, a fall in the barometer coincided with a rise in the water-line, and under conditions of high barometric pressure the water-line was lowered. Percolating gauges also gave similar evidence, for after percolation had ceased, and the filter was apparently dry, a rapid fall of the barometer occurring, a small quantity of water passed from the percolating gauges. The conclusion arrived at was, that atmospheric pressure exercises a marked influence upon the escape of water from springs.

The researches of Professor Cohn show that, in the fever-field of Breslau, the well-waters are never free from the fungus he calls *Crenothrix polyspora*. Dr. Klein, after numerous post-mortem examinations of enteric-fever cases, believes the cause of such fevers to be a vegetable germ, probably identical with that found by Prof. Cohn; and Mr.

* 'Nature,' September, 1881.

Baldwin Latham suggests that the porous, damp-soil covering of gravel-covered, fissured chalk affords all the requirements for such low fungoid growths. Be this as it may, the conditions under which pollution is likely to occur are perfectly evident, and no public water supply should be tolerated until means have been taken to exclude all sources of danger; or, in the words of Mr. Simon: "It ought to be made an absolute condition for a public water supply that it should be uncontaminable by drainage."