A MOBILE HYGIENE LABORATORY IN FLANDERS, 1917.

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The Laboratory.

The mobile laboratory built on a three-ton Daimler motor chassis was fitted out with all the equipment necessary for routine chemical and bacteriological examinations, the combined weight being five tons. Photographs of the exterior and the interior of a mobile laboratory may be seen on pages 11 and 12 of Volume I, Hygiene of the War, in the official "History of the Great War, Medical Services."

Taken over in London by the writer in November, 1916, the laboratory was shipped with three others of a similar type to Rouen. The laboratories were parked temporarily at the Convalescent Depot south of the city until required for service, and from time to time as the need arose they were despatched to various destinations in France, this laboratory (No. 23 Hygiene) being the last to receive orders to move.

The morning of June 19, 1917, saw us setting out for Abbeville, the next day St. Omer was reached, and the journey ended on the 21st when the laboratory was parked in the yard of a school in the Rue du Bassin, Poperinghe, to the west of Ypres. The area to be worked from Poperinghe comprised the portions of Belgium and France occupied by the Fifth British Army commanded by General Gough. There followed a strenuous week occupied in unpacking, making up media, and fitting up a room in the school as a workplace.

The Work of the Laboratory.

From June 19 until December 17, when the laboratory was ordered to join the British Forces in Italy, a succession of water samples collected personally, or forwarded, were dealt with, varied by such miscellaneous tasks as the examination of two samples of tea, thought to contain an excessive amount of tannin and hence believed to be the cause of constipation amongst the troops (only 6 per cent in one sample and 8·4 in the other was found, both being within the normal 6 to 12 per cent tannin), rice, which proved to be overgrown with aspergillus and other moulds, lime juice to calculate the amount of sugar and water to be added to render palatable, tinned herring in tomato sauce, also pork and beans (tins blown—numerous organisms present on culture), a soda water which was satisfactory on

[1] Summary of Dr. McNaught's Presidential Address to the Yorkshire Branch of the Society of Medical Officers of Health, 1938-39. Reprinted from *Public Health*, by kind permission of Dr. McNaught.

chemical examination but had been made from a water impure bacteriologically, and tablets found at a well in the forward area. The latter (possibly of German origin) appeared to consist of acid sodium sulphate with an aromatic flavouring substance suggesting a pine-oil derivative and were reported on as probably water-sterilizing tablets.

Another sample was that of green camouflage material which had been used to cover water tanks in the forward area. After soaking in water, the green colouring matter detached was examined, but was not found to contain any poisonous metals. It was advised that the material should not be allowed to dip into the tanks. A white powder submitted proved to be only sodium bicarbonate. Lastly, a tin of " Pure Cream Butter—extra choice variety " was forwarded as the contents appeared rather waxy and had a peculiar taste and odour like tallow. Analysis gave the figures: Water 9·5 per cent, fat 8·21, curd 1·5, ash 3·7, salt 2·7, and as only 0·27 per cent of boron compounds was found, together with a Reichert-Wollny figure of 25·4 per cent, the butter was pronounced to be apparently free from chemical adulteration. Its taste and odour were ascribed to the presence of (*a*) a small Gram-negative bacillus (which did not ferment sugars) and grew aerobically on agar at 37° C., and (*b*) a short stout Gram-positive bacillus, which grew scantily on agar in anaerobic culture at 22° C., but more plentifully at 37° C.

The chemical and bacteriological methods employed were those in common use in 1914, so far as suitable for a laboratory working in the field. For water analysis Thresh's " Water and Water Supplies " was the standard reference book.

On July 30, 1917, a sample of water drawn from the moat at Ypres was obtained for examination as it was stated that there was a " mustard " or " greenhouse " odour perceptible in the vicinity, and it was suggested that gas might be dissolved in the water. On inquiry it was learned that on July 12 to 13 gas shells had been used by the Germans and that analysis of the liquid filling had shown the presence of 70 to 80 per cent dichlorethyl-sulphide, with small amounts of hydrocyanic acid and carbon disulphide. No evidence of these was found in the sample of water from the moat.

This was our first introduction to the " blister " gases. With the use of chlorine, phosgene and tear gases in the forward areas, we had already become familiar. Now we found there would be others to deal with and were accordingly on the look-out for new ones, with amusing results. Soon after a shell burst in a part of the town near the laboratory and the explosion was followed by the most abominable and persistent stench. Respirators were hastily donned and investigation of the " new gas " was set afoot. The mystery was solved when it was discovered that a large and well-filled cesspool in the neighbourhood of the laboratory had been blown up and the decomposing contents scattered far and wide.

On another occasion a complaint was received from the inhabitants of the village of Buysscheure that certain wells had been poisoned. On taking

a sample I found that the water on standing showed at the surface an oily film smelling of cresol. Disinfectant had been poured down the drains of some of the houses by troops billeted in them and the cesspools had leaked into the wells and contaminated the village water supplies.

Water Samples.

Examination of water samples formed the bulk of the work. These were obtained from (*a*) shallow wells, (*b*) deep wells, and (*c*) streams over a strip of country extending from the forward trenches occupied by the troops attacking the Passchendaele ridge, through the devastated region of mud and water-filled shell-holes encircling Ypres to the less disturbed country in the vicinity of Poperinghe, back to the district of St. Omer.

Weather conditions, speaking generally, were fine until the end of July, when there came a change with heavy rain. This coincided with the opening of the British push towards Passchendaele and an advance to the Steenbeek. The forward area quickly became a quagmire. The autumn also brought much rain. Earlier samples were thus taken under dry conditions, but later in wet weather.

Geology of the Area.—The predominating feature of the area is the very thick "Ypresien" deposit of clays corresponding in age to the London clay and thus of lower Eocene age. Beneath are sandy "Landenien" deposits, the equivalent of the English Thanet beds. Those in Belgium are of the greensand or glauconitic type and were reached in the wells at 400 to 500 feet depth.

Results of Analysis.

Shallow Wells of Ypres or Forward Area.—Nine samples from the area lying to the north-east of Ypres, between the Yser Canal and the Steenbeek, were examined. The soil had been thoroughly churned up by three years of bombardment and in many places was a morass of sticky mud reminding one of an uncooked Christmas pudding, in which the bodies of men, animals, unexploded shells, and other miscellaneous débris took the place of fruit and formed the only stepping stones by which access could be gained to the wells. Pools of muddy and filthy water were all around, and as one would expect there was pollution of the wells to an extreme degree.

To the naked eye most samples presented a more or less turbid appearance, the colour varying from "almost colourless" and "pale straw" to "dark brown."

An offensive odour was detected in the water from Civilization Farm, and a microscopic examination of the sediment showed the presence of macerated organic matter in which cotton fibres could be recognized. Excluding this sample which gave the extraordinary figure of 3 parts per 100,000 free and saline ammonia, the average was 0·458 part or one hundred times the figure for a fairly satisfactory water.

Albuminoid ammonia ranged from 0·018 (well in a mine tunnel) to 0·5,

the average being 0·173 part per 100,000, seventeen times more than found in peaty waters. Oxygen absorbed from potassium permanganate in two hours varied from 11·2, an average figure for crude sewage, to 1·2. Total solids reached the highest at Below Farm, 400 per 100,000.

Chlorine in parts per 100,000 averaged 27·4 and varied from 65 to 2·5. Nitrates reached 20 per 100,000 at Below Farm, possibly due to pollution by the decomposition products of an explosive ; at Venheule Farm 12 parts were recorded. Iron 2·2 parts were found in one sample. Considerable amounts of magnesium salts were present in one sample, sulphates being recorded as 21 parts.

Bacteriological examination showed lactose fermenters absent in 0·1 millilitre and 0·2 millilitre, but present in 0·5 millilitre and higher amounts in one sample from Houthoulst Forest. In all the other samples lactose fermenters were present in 0·1 millilitre and larger quantities.

In the vicinity of Ypres most samples were turbid or opalescent ; one showing a deposit, not only of quartz, mica and vegetable debris, but also of glauconite. Magnesium and other sulphates reached 32 and 33 parts in two specimens, with chlorine figures of 44 and 22 and total solids of 280 and 210, hardness of 54 and 44, suggesting origin from London clay deposits (Ypresien). Nitrates or nitrites were present in every sample.

In all cases bacteriological findings were unfavourable, lactose fermenters being found constantly in 0·1 millilitre. To the east and south-east of Ypres samples were taken in dug-outs, the fourth specimen being from a steel-lined well about 90 feet deep in Larch Wood. These were apparently less polluted than specimens from the more northern sectors.

Chlorine figures were comparatively low, only 4·8 at Fosse Wood. The oxygen absorbed reached only 0·072 at Railway Wood. The presence of iron was noted in proportions of 1 to 2 parts per 100,000.

All the specimens gave similar results bacteriologically, lactose fermenters in 0·1 millilitre and larger amounts.

AVERAGES FOR YPRES SERIES (18 SAMPLES).

Ammonia (free and saline)	0·246
Ammonia (albuminoid)	0·126
Oxygen absorbed	1·07
Solids (total)	150
Hardness (total)	27·6
Chlorine as chlorides	21·7

Let us compare certain of the foregoing figures with those which have been suggested as standards for a " good sewage effluent."

	Ypres wells	"Good sewage effluent"
Free and saline ammonia	0·246	1·50
Albuminoid ammonia	0·126	0·15
Oxygen absorbed	1·07	1·50
Chlorine	21·7	10·0

Certain figures (ammonia and oxygen absorbed) for Ypres waters are

rather better than those for a good sewage effluent; on the other hand chlorine is doubled. Little can be said in their favour as potable waters.

The sample from Civilization Farm can be compared only with average figures for "crude sewage."

	Civilization Farm water	"Crude sewage"
Free and saline ammonia	3·0	6·5
Albuminoid ammonia	0·5	1·5
Oxygen absorbed	11·2	10·0
Chlorine	55·0	10·0

Note that its chlorine figure is five and a half times that of crude sewage.

Shallow Wells of Poperinghe or Mid-Area.—The waters of the second or Poperinghe group may be arranged under three heads: (1) Three samples from Vlamertinghe, east of the town on the road to Ypres; (2) four from the districts to the north and east; and (3) five from the town itself.

(1) The appearance varied from clear and bright to slightly turbid, free and saline ammonia from 0·0008 to 0·06, albuminoid ammonia 0·028 to 0·105, oxygen absorbed 0·09 to 0·26, total solids 26 to 50. The water from the Château had been treated by a water-sterilizing plant and no lactose fermenters were found in 50 millilitres of the water. The number of organisms on gelatine was 480, on agar 37.

(2) The chemical results of the samples showed less wide variations than met with in general. The bacteriological results of one set of samples were similar and good—no lactose fermenters in 50 millilitres, while others showed fermenters present in 0·1 millilitre and upwards.

(3) Of five samples from Poperinghe itself, two were clear, one opalescent, one turbid with whitish deposit, and one had a violet tinge, which proved to be pigment in a growth of algæ.

Free and saline ammonia ranged from 0·01 to 0·08, albuminoid from 0·015 to 0·06, oxygen absorbed from a low figure of 0·003 to 0·58.

Nitrates or nitrites were found in several samples. Lactose fermenters were present in amounts of 0·1 millilitre upwards, except in the 12-feet deep well to the south-west of Poperinghe where the fermenters were absent in 0·1, 0·2, and 0·5 millilitre, but present in 1 millilitre upwards.

AVERAGES FOR POPERINGHE SERIES.

Ammonia (free and saline)	0·026
Ammonia (albuminoid)	0·045
Oxygen absorbed	0·23
Solids (total)	65
Hardness (total)	17·2
Chlorine as chlorides	9·5

Shallow Wells of St. Omer, Western or Base Area.—The Western group may be divided into three sets, namely (1) three from the district to the west of Poperinghe, (2) six from the area round the north of Cassel, and (3) five samples taken from wells north-west of St. Omer.

(1) The samples did not differ greatly in certain respects, free and saline ammonia ranging from 0·001 to 0·003, albuminoid from 0·012 to 0·025, oxygen absorbed from 0·26 to 0·37.

Chlorine, however, varied from 1·6 to 8. One well showed lactose fermenters absent in 50 millilitres though the growth on gelatine gave 22,400 per millilitre and on agar 8,000 per millilitre.

Two samples showed lactose fermenters present from 0·1 millilitre upwards.

(2) Of the six specimens from Cassel district one was that smelling of cresol as previously related. Its ammonia and oxygen absorbed figures were high; bacteriologically it was bad—285,000 organisms on gelatine and 153,600 on agar. Vegetable débris was present in three samples and specimens of cyclops in two.

(3) The last group of samples from St. Omer neighbourhood contained one which was turbid with vegetable débris and fair numbers of cyclops.

Free and saline ammonia varied from nil to 0·029, albuminoid from 0·004 to 0·22, oxygen absorbed from 0·02 to 0·33. The lowest chlorine figure was 4·5; the highest 9 parts per 100,000.

Some waters contained lactose fermenters in 0·1 millilitre upwards, while others showed these absent in amounts below 10 millilitres. One sample gave only 2,400 organisms on gelatine and 400 on agar.

Omitting the Buysscheure specimen contaminated with cresol we get the following figures:—

AVERAGES FOR ST. OMER OR BASE SERIES.

Ammonia (free and saline)	0·019
Ammonia (albuminoid)	0·036
Oxygen absorbed	0·16
Solids (total)	53
Hardness (total)	15·0
Chlorine as chlorides	5·3

Deep Well Waters.—So far these notes have related to shallow wells. There was also dealt with one sample from a well at Houkerque, sunk through superficial strata and Ypresien clay, striking the Landenien greensand at 370 feet and of a total depth of 399 feet.

This specimen, though taken from the settling tank, was still turbid, the deposit giving evidence of the presence of glauconite. Its free and saline ammonia was low, 0·003, while albuminoid ammonia reached 0·01. Oxygen absorbed was high at 0·6. Total solids figure was 110. The water was not hard, only 5·8, and chlorine 17·6, was typical of a greensand water. No nitrates or nitrites were found.

Pollution of the tank by dust was probable, the number of organisms on agar being 4,700 and on gelatine 40,000. Lactose fermenters were found in 10 millilitres and upwards but not in 1 millilitre or smaller amounts.

During the period September 12 to November 24 nine samples were taken at the Laiterie, Poperinghe, from "Gough's Well," about 500 feet deep and sunk to the greensand.

Specimens taken direct from the freshly pumped water before settling were opalescent or turbid. On settling they became clear and bright and a grey-green deposit of quartz, ferro-magnesian minerals, and glauconite, was thrown down.

Free and saline ammonia varied from 0·018 to 0·06, albuminoid from 0·0004 to 0·07, an extraordinary range in amount. Oxygen absorbed highest figure was 0·25 and lowest 0·008. The figure for total solids lay usually in the region of 110 to 120, but on one occasion it fell to 40 and on another rose to 130. Hardness was from 2 to 8. Chlorine was very constant between 26·5 and 28. Only a trace of nitrates was found on one occasion. The residue contained much sodium carbonate.

Bacteriologically the worst specimen showed the presence of lactose fermenters in 0·1 millilitre upwards, and the best, absence in 0·1 millilitre, 0·2 millilitre, 0·5 millilitre, and 1·0 millilitre, presence in 10 millilitre upwards. Averages worked out for the series of nine tests :—

Ammonia (free and saline)	0·039
Ammonia (albuminoid)	0·019
Oxygen absorbed	0·09
Solids (total)	110
Hardness (total)	3·6
Chlorine as chlorides	27·3

Water Samples from Streams, Rivers, Canals, and Lakes.—These samples were taken over the area extending from the Steenbeek sector to the east of Ypres, occupied by the front line troops to the Canal de la Colme and the Canal de l'Aa, north of St. Omer at the base.

After the period of heavy rainfall which held up the British offensive in August, the water from the Steenbeek was very turbid and threw down a clayey deposit. There was a moderately high free ammonia 0·01, while albuminoid reached 0·25 and oxygen absorbed was very high at 2·3. Chlorine figure was 3·6. Note that iron was present 12 parts per 100,000, possibly due to the enormous amount of metal débris from exploded shells and other war material.

Two samples from Bellewards Lake gave 0·35 and 0·248 parts free ammonia, albuminoid 0·097 and 0·136.

Next came a series of water samples from the moat surrounding Ypres and from the Yser Canal to the north of the town. Some were fairly clear, others opalescent or turbid and brownish in colour. Averages for the series worked out as follows :—

Ammonia (free and saline)	0·069
Ammonia (albuminoid)	0·099
Oxygen absorbed	0·48
Solids (total)	48
Hardness (total)	8·7
Chlorine	8·1

Further west four samples were taken from Dickebusch Lake and one from its effluent stream the Dickebuschbeck near the Ypres laundry. The

average of the four lake tests is here set out in contrast with the result of analysis of the stream :—

	Lake	Stream
Free and saline ammonia	0·032	0·006
Albuminoid ammonia	0·087	0·068
Oxygen absorbed	0·69	0·69
Solids (total)	20	20
Hardness (total)	6·4	7·0
Chlorine	2·9	1·6

The stream, in addition to the outflow from the lake, received water of obviously purer character from streamlets and springs. The lake was used as a source of supply by the British forces; the water was chlorinated before use for drinking.

Two samples from the neighbourhood of Poperinghe illustrate clearly pollution derived by the water in its passages through a populous place from which surface washings have entered :—

	Vleterbeek	Canal
Free and saline ammonia	0·04	0·27
Albuminoid ammonia	0·032	0·17
Oxygen absorbed	0·38	0·79
Solids (total)	40	50
Hardness (total)	12·5	11·5
Chlorine	3·3	5·2

The Eybecque, the boundary stream between France and Belgium, had been used as a source of drinking water for horses, and this supply was suspected to have produced colic in these animals.

With free and saline ammonia 1 part per 100,000, albuminoid 0·1 part, oxygen absorbed 2 parts and chlorine 5·4, it gave a result approximately equivalent to a mixture of 2 parts of sewage to 1 part of pure river water. One therefore did not rule it out as a possible source of colic !

Last of all are the two samples from the Canal de l'Aa, St. Momelin, and the Canal de la Colme at Schapstadt, north-west of St. Omer.

These canal waters were relatively pure, 0·006 and 0·004 part of free and saline ammonia and only in the Canal de la Colme was the albuminoid figure high. Oxygen absorbed was not excessive, 0·42 and 0·38.

Note also, nitrate 0·01 in the Aa, but chlorine was only 2·5 and 2·6. Bacteriological results were, lactose fermenters absent in 0·1, 0·2, 0·5 millilitre, present in 1 millilitre (Colme), and absent in 0·1, 0·2, 0·5, 1 millilitre, present in 10 millilitres (Aa).

Compare the averages for (*a*) these two fairly pure canal waters; (*b*) the Vleterbeek stream at Poperinghe; (*c*) the Ypres moats and Yser canal.

Rivers and streams.	Canals, Colme and Aa.	Vleterbeek, Poperinghe.	Ypres moats and Yser Canal.
Free and saline ammonia	0·005	0·01	0·069
Albuminoid ammonia	0·023	0·032	0·099
Oxygen absorbed	0·40	0·38	0·48
Chlorine	2·45	3·3	8·1

Let us now turn from the demonstration of the increasing pollution of rivers, canals and streams as we pass from the base to the forward area, and compare the results with a summary of those previously obtained from the examination of shallow well waters, again using the three divisions, West (St. Omer), Mid (Poperinghe), and East (Ypres), or respectively base, intermediate and forward areas.

Shallow wells	West or St. Omer area. (Average of 18 samples)	Mid or Poperinghe area. (Average of 12 samples)	East or Ypres area. (Average of 14 samples)
Free ammonia	0·019	0·026	0·246
Albuminoid ammonia	0·036	0·045	0·126
Oxygen absorbed	0·16	0·23	1·07
Total solids	53	65	150
Total hardness	15·0	17·2	27·6
Chlorine as chlorides	5·3	9·5	21·7

This table demonstrates clearly the increasing pollution of shallow wells as we pass from the comparatively undisturbed base area near St. Omer to the devastated area in front of and around Ypres, the scene of so many struggles between opposing armies that the soil had become saturated with decomposing organic material.

It is the hope of the writer that in compiling these notes and adding his comments he may have made some slight contribution to the study of the water supply problems which confront us in peace no less than in war.