REPORT

ON THE

CHEMICAL WORKS

OF SOUTH SHIELDS

This essay had its origin in intention as a report to the Local Authority. I soon perceived that the subject was susceptible of such treatment as to make the results possible to be presented as a thesis for the degree of D.Sc. The official nature of the investigation enabled me to make the inquiry more thorough than if conducted as a private affair, and the census of the town which I was empowered to make in connection with it materially contributed to the value of the results. I have not thought it necessary to alter the few phrases in the report which are more particularly addressed to the Local Authority: the report was undertaken and made out essentially for the purpose of presentation as a D.Sc. thesis.

A. C. M.
REPORT
ON THE
CHEMICAL WORKS
OF SOUTH SHIELDS
IN THEIR
RELATION TO THE PUBLIC HEALTH.

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Under the convenient designation of Chemical Works, I include the Alkali Works, Glass Works, and Gas Works of the district, in all of which more or less definite chemical processes are carried on, and from all of which products of a more or less definite chemical composition are liable to escape into the atmosphere. In accordance with the desire of the Committee, I have repeatedly visited these works for the purpose of informing myself as to the processes carried on in them, and have endeavoured to differentiate their effects on the health of the town by means of the sanitary statistics of the past. As the result of my inquiries, I have to submit the following Report:

I. THE ALKALI WORKS.

Of these, as you are aware, there are three within the district—those of the Tyne Alkali Co., the Jarrow Alkali Co., and the St. Bede Alkali Co.

In the works of the Tyne Alkali Co. the manufacture of Carbonate of Soda, and Chlorate of Potash is carried on.

In the Jarrow Alkali Works Carbonate of Soda, Bi-carbonate of Soda, and Caustic Soda are produced.

At the St. Bede's Co.'s works, Carbonate of Soda and Bleaching Powder are the final results of the operations carried on.

In all of these works the manufacture of sulphuric acid is carried on as an intermediate step to the production of the carbonate of soda or "Soda-Ash" as it is called. The first step towards the manufacture of sulphuric acid is, as you know, the roasting of cuprous pyrites—bi-sulphide of iron, with a small admixture of copper, and containing about 49 per cent. of sulphur: the sulphur burning, that is, combining with oxygen—forms sulphurous acid gas (SO₂), which passing over into the lead chambers is thus oxidized by means of nitric acid vapour and steam into sulphuric acid (H₂SO₄ or H₂SO₃). The nitric acid is recovered and the sulphuric acid concentrated, by means which I need not now describe.

* I have in this connection to acknowledge my indebtedness to the very lucid and interesting Reports on Effluvium Nuisances by Dr. Ballard, and to the standard work of Dr. Lunge on "Alkali."
In this first process an escape of gas productive of annoyance outside may occur at two or three points. In the first place from the pyrites burners: here an escape is possible through chinks and cracks which form if the brick-work is allowed to become dilapidated, or from crevices about the doors; and to a greater extent (from insufficiency of draught) from the doors themselves when they are being charged. I need hardly remark as to the necessity of maintaining the plant in good repair. Various opinions prevail as to the relative advantages of hinged and sliding doors: in either case care must be taken that any chinks which may arise are well luted. The regulation of the draught is a matter of some delicacy; in the interest of the manufacturer too great a draught is undesirable as tending unduly to dilute the gas passing over and for other reasons: while if too much restricted the gas tends to escape through imperfectly fitting doors or other accidental crevices. To prevent the nuisance of escape from the feeding doors which may occur even when the chambers are working well, it is only necessary to close all the ash-pit doors before the door of the furnace to be charged is opened: in this way the necessary supply of air being forced to enter through the only open door any reflux of gas is rendered impossible. The escape of gas from the “nitre-pot” in which the nitric acid is generated may be prevented by the same means. It is obvious that “constant watchfulness is requisite in respect of the leaden chambers” in which the conversion of the S O₂ into the S O₃ takes place “and in making necessary repairs.” The nuisance arising from imperfect condensation of the sulphuric and nitric acid produced is entirely avoidable by the proper working of the Lussac and Glover towers. The requirement of the Alkali Act is that “the acid gases of sulphur and nitrogen escaping in each cubic foot of air, smoke or gases from the chimney shall not exceed what is equivalent to four grains of sulphuric anhydride.”*

It is in the next stage of the process—the conversion of Chloride of Soda (common salt) into sulphate of soda (salt cake)—that the most obnoxious escape of gas is apt to occur. In this operation sulphuric acid is run in among the salt which is placed in the decomposing pans, and the mixture is

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* The condensation of these acid gases seems to be efficiently carried out in the borough. I am indebted to the kindness of Mr. Jackson, H.M. Alkali Inspector for the Tyne district, for the results of the analyses made by him during the three months ending October 31st, 1882. The subjoined table shows the mean of these analyses: on no occasion was the Government limit—which gives rather a liberal allowance, however, nearly reached.

| Total Acids of Sulphur and Nitrogen as S O₃, in Chamber outlets, in grains. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 | No. 1. | No. 2. | No. 1. | No. 2. | not more than |
| 1.47            | 23    | 1.06  | 1.39  | 1.55  | 4.00          |
exposed to a strong heat: the sulphuric acid acting on the salt produces sulphate of soda, and hydrochloric acid gas is given off \[2\text{NaCl} \rightarrow \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 \rightarrow 2\text{HCl}\] and is conveyed in flues to the condensers. The conversion of the salt into salt cake is completed in reverberatory furnaces called "roasters" which are continuous with the decomposing pans, and the hydrochloric acid given off at this stage is also led away to the condensers. These consist of towers 40 to 60 feet high, packed with coke or brick, into the top of which water is led: the water falling over the pieces of coke or brick is broken up into innumerable films, and thus a very large surface for the absorption of the hydrochloric acid gas is afforded.* In most cases during or shortly after raking up the fresh batch of mixed salt and acid—when the evolution of gas is most vehement, and also when shoving the batch from the pan into the furnace, a certain escape of hydrochloric acid is apt to take place through the doors or through crevices in the brickwork, especially if the draught through the condensers is insufficient. But the chief escape of gas occurs when—the roasting being completed—the salt-cake is raked out into (iron) barrows, and is being wheeled away to the storehouse. I find that the nuisance arising at this stage is often attributed by the public outside these works to chlorine. Some escape of this sort always takes place when the batches are being drawn, but it is sometimes excessive: it is greatest when the charge is drawn too early, and before it has been sufficiently roasted. If what is called a "strong" salt cake has been formed, the vapours are most sulphuric acid or anhydride, if "a weak" salt cake—then hydrochloric acid. The escape of acid gas at this stage I believe to be the most grievous nuisance associated with Alkali Works. The nuisance might be largely mitigated by either of two methods which have been adopted in some works, though not in any of the works in this district. The first is the erection of light vapour hoods of wood or cast iron over the doors and dampers, connected by fire-clay pipes with a well-drawing chimney: "the use of such hoods affords time for an efficient use of the next proceeding which ought always to be adopted, namely, the covering of the hot and freshly-drawn salt cake with cold salt cake patted down upon it before the barrow is wheeled away. Workmen often neglect this precaution on account of the trouble of bringing cold

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* The subjoined table, which gives the mean of the analyses carried out by Mr. Jackson during the three months ending October 31st, 1882, shows that the hydrochloric acid escaping condensation in the Alkali works of this district has been well within the limit of the Alkali Act.

<table>
<thead>
<tr>
<th>HCl per cubic foot in Gases escaping from Chimney, in grains.</th>
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<td>No. 1.</td>
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salt cake to the mouth of the furnaces." And, indeed, I have not observed this precaution being taken at any of the works in town. But perhaps a more efficient method is that adopted at the Netham works, where "the charge from the roasters is drawn through an aperture provided in the floor of the roaster into a space below, closed in front by an iron plate with an aperture in it for the admission of air. The fresh salt cake is left here to cool for half an hour, the acid vapours passing by a flue from the chambers to the chimney," or better still to a condenser if practicable. In any case it is necessary that care should be taken that batches are not too soon drawn.

In the Jarrow Company's Works part of the salt cake produced is manufactured by means of Hargreave's process. In this mode of operation there is no intermediate manufacture of sulphuric acid, the sulphurous acid gas from the pyrites-burners being led at once, together with steam and a certain proportion of air, through a series of heated cylinders containing moulded lumps of common salt \[2NaCl + S O_3 + H_2 O = Na_2 S O_4 + 2HCl\]. The gases are drawn through for ten days or so, then shut off for a night; air is then drawn through the cylinders to remove any unabsorbed gas. The advantages claimed for this process are "the steady evolution and easy condensation of the hydrochloric acid, comparative freedom from nuisance of escaping gas since the lead chambers and decomposing pans and furnaces, always wanting repairs and difficult to keep gas-tight, are replaced by gas-tight cylinders into which gas is aspirated and from which it thus cannot leak out."* It is to be hoped that this process may turn out as profitable commercially as it is desirable hygienically, and that it may soon become general in Alkali works.

In the further processes of the conversion of Sulphate of Soda into "black-ash," in which the Sulphate of Soda is strongly heated, together with crushed coal and limestone or chalk \[Na_2 S O_4 - C_2 - Ca C O_3 = Na_2 C O_3 - Ca S - 2C O_2\] and the "lixiviation" or dissolving out from the black-ash of the Carbonate of Soda thus formed, no appreciably obnoxious emanation is given off.

In the Jarrow Co.'s works the further processes carried on are the manufacture of Caustic Soda by the action of slaked lime in Carbonate of Soda in solution \[Na_2 C O_3 - Ca H_2 O_3 = 2Na H O - Ca C O_3\], and Bi-carbonate of Soda by the action of carbonic acid gas, in closed vessels in crystalized Carbonate of Soda \[Na_2 C O_3 - H_2 C O_3 = 2Na H C O_3\]: in these processes no nuisance arises.

In the Tyne Co.'s works the only manufacturing process carried on in addition to that of Carbonate of Soda, is that of Chlorate of Potash. The chlorine required for the purposes of the manufacturers is generated by the

* Dr. Lunge on "Alkali."
action of manganese di-oxide on hydrochloric acid in closed stills made of slabs of siliceous stone cemented and bolted together. The gas is led from the stills by means of stoneware pipes luted together, and is passed through three vessels in succession over the surface of a mixture of milk of lime and chloride of potassium solution, kept constantly agitated by means of machinery: the openings into these vessels are water trapped, having a “seal” of six inches. Provided the apparatus is in good working order and the regular generation of the gas is properly attended to, it is impossible that the chlorine should escape absorption in one or other of these vessels, the contents of all three never being saturated at once, but to meet such a contigency a pipe is led from the last vessel of the series to the old chloride of lime chamber, which is now only used as a reserve condenser for the gas. So little chlorine really passes into this chamber that when the lime is changed, perhaps once in two months, it has hardly any perceptible odour of chlorine. The mixed solution of chlorate of calcium and chloride of potassium is run into shallow evaporating pans in which chlorate of potassium crystallizes out. As a rough and ready method of preventing the escape of any appreciable quantity of chlorine from the saturated solution, before it is run into the crystallizing pans a few buckets of tank waste liquor are added to it in order to neutralize any excess of chlorine. The manganese di-oxide is recovered by means of the Weldon or “regenerative” process, in which the proto-chloride of manganese left as a residue from the chlorine-generating operation is mixed with excess of milk of lime, air is blown through the mixture, and steam sufficient to raise the temperature to 140°F., is passed in, the manganese di-oxide precipitate forming the “manganese mud” which is again used for the generation of more chlorine. In these processes there ought to be little or no escape of chlorine, unless through gross carelessness on the part of the workmen. As these works, from their unfortunate position in the heart of the town, are those which are most obnoxious to the community and most complained about, I think it right to remark here that several changes conducive to the mitigation of previously existing nuisances have been made since Dr. Spear reported on the subject in 1875—in the supersession of the chloride of lime production by that of chlorate of potash, the erection of additional hydrochloric acid condensers, and the deodorization of their tank-waste drainage by a method which involves a yearly expenditure of about a hundred pounds. While doing justice, however, to the efforts of the managers to minimize the offence to the public, I feel bound to say that I think it was most unfortunate that the re-establishment of Alkali works on such a site was ever sanctioned.

In the St. Bede Co.’s works beside the manufacture of Carbonate of Soda, that of Bleaching Powder or “Chloride of Lime” is carried on. The chlorine required is generated and the manganese recovered by similar processes to those adopted in the Tyne Co.’s works. The chlorine gas obtained by the
action of manganese di-oxide on hydrochloric acid is led by means of well-luted stoneware pipes into lead chambers about 6½ feet high, on the floor of which hydrate of lime—slaked lime—has been laid to a depth of about six inches, the doors being carefully closed and luted. After 36 to 48 hours exposure to the gas usually, the doors are opened to allow of the lime being turned; the doors being again closed the gas is passed in for 24 hours or as much longer as may be deemed necessary for the saturation of the lime. The gas is then turned off, and after an interval of 24 hours, or often somewhat longer, to permit of complete saturation, the doors are opened and are left open for a short time to allow of the dilution of the unabsorbed gas. The chambers are then entered by the workmen (wearing many-plied flannel "mufflers" in order in some degree to protect themselves from the gas), and the chloride of lime is shovelled into casks. In these processes there is of course a possibility of accidental leakages from the lead chambers, but these never exist to such an extent, I believe, as to give rise to a nuisance appreciable outside the works. An appreciable nuisance, however, may arise when the lead chambers are opened for the purpose of turning the lime or discharging the bleaching powder. The occupation of the men who have to enter these chambers and pack the powder must be pronounced decidedly unhealthy. The establishment of such a process as the Deacon (in which the saturation of the lime is effected by means which are not productive of nuisance outside of the works and in connection with which there are no chambers to be entered by the workmen) as a profitable commercial undertaking is much to be desired, more especially in the interest of the employés in such works. In some works, however, the nuisance is materially mitigated by means of appliances for drawing off the unabsorbed gas.

In connection with the subject of Alkali works it is necessary that I should say something of the "tank-waste" nuisance. What is known as tank-waste is the residue of the "black-ash" from which the carbonate of soda has been dissolved out. As the Committee are aware all the tank-waste produced in the district is now and has for some time past been carried out to sea in "hoppers" and discharged there. This mode of disposal is thoroughly satisfactory sanitorily, but is somewhat expensive and—from the abstract point of view at least—decidedly wasteful, in that all the sulphur which enters the works is thrown away in the waste. The community, however, especially at the west end of the district, have to suffer to a very serious extent for the sins of omission (on the part of the Sanitary Authority) and commission (on the part of the Alkali manufacturers) of preceding generations, in the disgusting odour of sulphuretted hydrogen, which arises from the drainage of the old tank-waste deposits at Jarrow and East Jarrow and permeates the atmosphere of these localities. Dr. Ballard remarks in his Report on Effluvium Nuisances, (in connection with which inquiry he must have had considerable
experience of evil odours), that he "never had the misfortune of such an exposure to sulphuretted hydrogen as on crossing the bridge over the river close to St. Bede's Church (Jarrow): it was sickening!" The drainage of the large waste deposits at Jarrow passes, as you are aware, into a tidal stream known as the Don: the sea water with each rise of the tide washes the banks of this stream and the base of the waste-heaps, thus constantly leaving as it recedes a fresh surface exposed to the air. The Don is perfectly turbid with deposited sulphur and gives off in its course to the river (during which it passes under the highway) a copious exhalation of sulphuretted hydrogen. This stream, however, does not pass into the Tyne at the nearest point, but pursues its sluggish course round the river side of the St. Bede works, all this time discharging more or less sulphuretted hydrogen. Opposite East Jarrow it receives a small tributary of a like offensive nature which brings down the drainage from a smaller deposit of waste at East Jarrow, and which also passes under the highway. The stream continues to flow eastward till it reaches the west end of Tyne Dock where it enters a channel which also discharges the contents of one of the large town sewers. The tedious passage of the waste drainage is, of course, periodically interrupted at high tide, and the rise of the tide seems to force back some of the drainage carried down by the Don into the town sewer which discharges into the same channel, giving rise occasionally to a nuisance along its course.*

If the nuisance from these tank-waste deposits at East Jarrow and Jarrow were likely to be merely of a temporary character, the Sanitary Authority might view the occurrence with equanimity, but there is no prospect of any material diminution of the nuisance for the next 30 or 40 years unless some active steps are taken in the matter. I have, therefore, thought it my duty in accordance with the provisions of the Alkali Act to direct the attention of the Chief Inspector of Alkali Works to the nuisance arising from these deposits. He assures me in reply that he is not unmindful of the matter, that he has set on foot a series of experimental researches at Widnes, where also such deposits give rise to considerable nuisance, and that when these trials are brought to a satisfactory conclusion he intends urging on the question elsewhere. The additional complication of the tidal wash exists at Jarrow, and unless this is prevented by means of an embankment it is difficult to see how any satisfactory mitigation of the nuisance can be attained.

It may be necessary to explain how the deposit of tank-waste in a district gives rise to offensive emanations. As discharged from Alkali works it consists mainly of sulphide, carbonate, and hydrate of lime—together with small quantities of coal, carbonate of soda, silica, iron, and alumina. Exposed for

* I may remark here that this is not an unmitigated evil, as it serves to give useful indications of defective trapping of house-drains. I should, however, recommend the replacement of the flap-valve which formerly existed at the outfall of this sewer.
a time to the action of the atmosphere oxidation of the sulphide of calcium goes on, and hyposulphite, sulph-hydrate, and polysulphides are formed, together with the corresponding sodium compounds. Part of the sulphur separates out, burns, and forms sulphurous and sulphuric acids—these, with the carbonic acid of the air, form sulphate and carbonate of lime, the former reacting on the small quantity of carbonate of soda present produces sulphate of soda. Finally, there ought to be nothing left but carbonate of lime, sulphate of lime, sulphate of soda, calcium and aluminum silicate, ferric oxide, coal, and some indifferent and harmless matters. Even after 30 or 40 years, however, unoxidized sulphur is still found in the interior of waste heaps. During this slow process of oxidation the rain washing through the waste-heaps, or, it may be, springs rising from below, carry away in solution calcium hyposulphite and the soluble sulphides of lime, in the form of a greenish-yellow drainage liquor. An analysis of such drainage liquor given by Dr. Ballard showed in 100 parts—calc. sulph-hydrate 76'3 parts, calc. hyposulphite 18'2 parts, and calc. polysulphides 5'5 parts. The sulph-hydrate (CaH S) and polysulphides (Ca Sx) acted upon as they flow by the carbonic acid of the air and soil give off sulphuretted hydrogen—the hypo-sulphite acted upon in the same way will give off sulphurous acid (which will neutralise a small proportion of the sulphuretted hydrogen formed) and deposit sulphur, this sulphur with the carbonate of lime also formed in situ constitutes the turbidity of the liquid. The sulphuretted hydrogen smell is worst in rainy weather from the carbonic acid of the air being washed down by the rain, and if the drainage is allowed to flow into a sewer the sulphuretted hydrogen will be more plentifully disengaged from the excessive amount of carbonic acid present in sewer gas. Of course, if the waste drainage comes into contact with acid drainage the evolution of sulphuretted hydrogen is still more copious, and the nuisance becomes still more aggravated.

A certain amount of tank-waste liquor drains away from an old deposit on the ground of the Tyne Alkali Company, and was at one time run directly into one of the town sewers, creating a nuisance which was much complained of all along its course. To obviate this Dr. Lunge, at that time manager of these works, devised a plan by which the drainage was intercepted and directed into a series of ponds together with the refuse from the Weldon “settlers”—this consisting chiefly of hydrate of iron, carbonate of lime, and some proto-chloride of manganese. The mud in the ponds is from time to time stirred up or shovelled out on the banks—to promote oxidation. In the course of these operations some such process as this goes on: the hydrate of iron and proto-chloride of manganese acting on the sulphides of lime form sulphides of iron and manganese, and hydrate of lime. The hydrate of lime acted upon by the carbonic acid of the air forms carbonate of lime which with that introduced in the refuse, settles to the bottom: the sulphides of iron and
manganese are oxidized more or less completely by the action of the air, depositing sulphur—which settles to the bottom, and reforming the oxides which are then ready to decompose more sulphide of lime. The supernatant liquid—at least when the process is thoroughly carried out—flows away inodorous and innocuous. A certain quantity of sulphate of lime is found in the effluent liquor: this is believed by Dr. Ballard to be formed by oxidation—through the intermediate formation of sulphate of manganese: it can, however, I think be accounted for by the proportion of sulphuric acid which is practically found to be carried over from the decomposing pans along with hydrochloric acid—this acid being subsequently used in the Weldon stills.

An insignificant quantity of waste drainage issues from a tank-waste deposit on the ground of the deposit in the ground of the Jarrow Co., but does not enter the Corporation sewers, being carried off through a drain* provided by the N.E. Railway Co., and discharged at the entrance to Tyne Dock, separately from the acid drainage from the same works.

II.—GLASS WORKS.

Before proceeding to consider the effects upon the public health of the presence in the district of the Alkali Works, whose operations I have just described, it will be convenient to give some outline of the processes carried on in the Glass Works, as they materially aid in the deterioration of the atmosphere by the evolution of similar acid gases.

Shortly after entering office here, my attention was directed to a nuisance in connection with the Tyne Plate Glass Works, consisting of a "gassy" smell, disagreeably appreciable especially in the Market Place, and more particularly when the wind was from the south-west. This was attributed entirely to the "gas producers" in use in these works, and a somewhat unfounded prejudice against these contrivances seems to have sprung up in the public mind. I should like, with your permission, to clear up the misapprehension which exists on the subject. I do not think that any nuisance arising in this department prevails to such an extent as to be appreciable in the Market Place, the stoke-holes of the gas-producers being situated by the river side and having the whole body of the works intervening and tending to dissipate any gases escaping there ere they can reach the centre of the town. I am of opinion that in the public interest the use of such gas-furnaces, conducted with proper precautions, should be encouraged as tending to hasten the

* This drain was recently choked up, giving rise to an eruption of the tank-waste liquor in the public road.
advent of the Siemens millennium of smokelessness—an era the blessings of which would be peculiarly appreciated in South Shields.* Such gazogenes have had their origin in the consideration that in ordinary furnaces the fuel or combustible matter and the atmospheric air are not brought into such relations as to produce anything like complete combustion of the fuel and the corresponding calorific effect, and in this way smoke and uncomsumed gas pass off into the atmosphere. The essential feature of such “gas-producers” as are in use in the Plate Glass Works is, as you are aware, the generation of crude coal gas in a set of what may be called “retort-furnaces,” for consumption when lead to the point at which heat is required, where it is met by a current of (generally) heated atmospheric air. In these gazogenes the fuel which is to produce the gas is placed—not, as is the case in Gas Works which supply gas for ordinary illuminating purposes, in closed retorts heated by separate furnaces—but in the furnace itself, a limited supply of air being admitted, sufficient only to produce the heat required for distilling the gas from the super-incumbent fuel. In the lower part of the furnace, to which the air is admitted, by the combustion there produced carbonic acid gas (CO<sub>2</sub>) is formed; this rising through the mass of red-hot coal (mainly carbon) overhead, is reduced, that is, has part of its oxygen taken from it, and forms carbonic oxide gas (CO); this is led to the glass-fusing furnace of which it forms the fuel, and there—in admixture with atmospheric air previously heated by the Siemens regenerative process—is burnt into carbonic acid, thereby yielding the requisite heat. In the newer range of furnaces—known as Wilson’s Patent—a jet of steam is also introduced at the lower part of the furnace, this is decomposed in the interior, and the gas produced in these constitutes what is described as a “richer” fuel, that is, one of greater calorific power.

A nuisance to a limited extent does arise in connection with the operation of these gas-producers: the gazogenes are charged from above by means of “bell-mouths” or “boxes” as they are variously called,—these are separated from the body of the furnace by, at least theoretically, gas-tight valves, kept closed by means of a counter-poise. A charge of fuel is introduced into each box every half-hour or so—the counter-poise is raised—and the charge descends into the furnace: of course, the gas rushes out till such time as the valve is again closed, and if the stoker is careless or inexpert it can be under-

* In this connection the following quotation is of interest:—“Professor Roberts has calculated that the soot in the pall hanging over London on a winter’s day amounts to fifty tons; and that the carbonic oxide, a poisonous compound arising from the imperfect combustion of coal, may be taken as at least five times that amount. The fine dust resulting from the imperfect combustion of coal is mainly instrumental in the formation of fog, each particle of solid matter attracting to itself aqueous vapour: these globules of fog are rendered particularly tenacious and disagreeable by the presence of tar-vapour, another result of imperfect combustion of raw fuel.”

Dr. Siemens’s Presidential Address, Brit. Assoc., 1881.
stood that a considerable escape of gas may take place at such times. In a smaller degree an escape of gas takes place each time the gas-producer is stirred up—the stirring-rod being introduced from above through holes placed around the charging orifices. I have to remind you that the gas which is here spoken of as escaping consists mainly of carbonic oxide—a gas which when inhaled produces dangerous effects on the animal economy. One-half per cent. in the air breathed would produce poisonous symptoms, and anything over one per cent. would be pretty rapidly fatal. Of course, when largely diluted, as the escape here taking place soon becomes, the results are not nearly so evident, but even then it must be more or less prejudicial to the workmen employed about these furnaces. Speaking of these gazogenes a classical writer* says:—"From the exceedingly poisonous nature of carbonic oxide it is of the utmost importance to prevent the escape of unburnt gas; and if this cannot be prevented the escape must be fired when the charging-hole is opened. This is regularly done in blast-furnaces working with gas-collecting flues; and even the native iron-smelters of India in starting their small furnaces with stacks only a few feet high, observe the same precaution."

As a practical remedy for the nuisance arising here I would suggest the addition of a gas-tight lid over the mouth of each charging box, and the leading of a gas-escape-pipe from each charging box to the furnaces. Each time a charge was introduced into the box the lid would be closed ere the valve communicating with the body of the gas-producer was opened—when this was opened and the gas had rushed up into the box it would be at once sucked off into the furnace where it would be burnt. An automatic arrangement might easily be attached by which the aperture of the gas-escape-pipe would just be uncovered as the lid was shut: in this way there would be no unnecessary admission of cold air into the furnace. With respect to the stirring-holes I would remark that if introduced into the lower part of the furnace they would be equally effective, and their use would not be attended by any escape of gas.

As I have already indicated, however, the nuisance attributed by the public to the "gas-producers" arises in another fashion: it occurs in the process of glass-making. Glass is, as you are aware, "a mixture of insoluble silicates produced by the fusion together of materials, the precise nature and proportions of which vary with the kind of glass to be made, and to some extent also in different works making the same kind of glass." In the plate-glass works in this country the ingredients used are sand, lime, sulphate of soda, "cullet" (broken glass), and a little arsenious acid ("white arsenic").† The mixture

† The composition for a "mixture" for French plate-glass-making is given as—white quartzose sand 100 parts, carbonate of soda 33'3 parts, slaked lime 14'3, manganese dioxide 0'15 parts, "cullet" 100 parts.
is exposed for the purpose of fusion to the very high temperature of the furnace, the products of the combustion of the fuel and gases—consisting mainly of sulphuric acid from the sulphate of soda—given off from the cast, passing off together and being led through the flues of the Siemen’s Regenerator, are discharged into the atmosphere in the case of these works from a comparatively low chimney. The Tyne Plate Glass Co. have declined to furnish me with information as to the quantities of the various ingredients used in their works on the ground that these are trade secrets. I am therefore unable to inform the Committee with certainty as to the extent to which these works contribute to the contamination of the atmosphere. But supposing—a fair enough guess for works of the size of these—that 5 tons of sulphate of soda were used per diem, that would imply a daily discharge of 2 tons, 16 cwt. of sulphuric anhydride ($S\text{O}_3$), or 3 tons, 9 cwt. of mono-hydrated sulphuric acid ($H_2S\text{O}_4$).* The usual proportion of arsenic used in plate-glass works is, I find, about 5lbs. to the ton of sulphate of soda, which would imply, on the basis above assumed, the daily use in these works of a quantity amounting to 25lbs. It is possible that a proportion of the arsenic remains as a constituent of the glass in the form of a double silicate, but from the volatility of the arsenic compounds in general we may fairly assume that at the temperature of these furnaces the greater part passes off into the atmosphere. The quantity is not large from the avordupois point of view, but when we recollect that two grains of arsenic may prove a fatal dose even for an adult, and that in very much smaller doses continued for a time are sufficient to cause symptoms of chronic poisoning, the volatilization of even this quantity of arsenic in the centre of the town cannot be regarded without apprehension by the Sanitary Authority. The evolution of acid fumes other than those which result from the combustion of coal would not occur if carbonate of soda were used instead of the sulphate: the sulphate is however cheaper, and it is asserted—probably with perfect truth—that it would be impossible to maintain the competition with foreign manufacturers if the glass-founders in this country were compelled to use the carbonate. Assuming then that the use of the sulphate in glassmaking is a commercial necessity, the first expedient which suggests itself for the abatement of the nuisance is the condensation of the acid gas evolved. Schott, indeed, has proposed to utilize the acid given off in making glass for vitrol-making, the gas to be made richer in sulphur by employing in the glass-mixture sulphate of lime (gypsum) instead of limestone. Dr. Lunge remarks, that “it is doubtful if this is practicable, since such diluted gas (mixed with a great deal of $O\text{O}_3$) has not yet been utilized.” The main difficulty, however, arises out of the high temperature at which the fumes reach the chimney. No method appears yet to have been

* From the “reducing”—that is, deoxodizing—action of the furnace the sulphuric acid appears to be partly decomposed and given off in the form of sulphurous acid.
devised by which sufficient cooling of the gases to effect their condensation can be attained without undue interference with the draught of the furnaces. Under the circumstances the only remedy which suggests itself in connection with the discharge of the acid fumes, is a palliative one—that they should be discharged from a chimney-stalk of such a height as will secure their thorough diffusion and attenuation before they descend upon the surrounding district. With respect to the arsenical nuisance, however, the case is different: the arsenious acid appears to be used merely as an oxidizing or bleaching agent; in many places manganese dioxide, or nitrate of potash, is used instead—the use of these substances would not be productive of nuisance, and I think it is a matter for consideration whether the substitution of one or other of these should not be insisted upon in the case of works situated in populous districts.

A further evolution of sulphuric acid takes place at the Polishing Works of the Tyne Plate Glass Co. There crystallized sulphate of iron (copperas) is roasted for the purpose of furnishing the oxide of iron (rouge) used on the polishing tables. In this process first the water of crystallization of the sulphate is driven off, and then mono-hydrated sulphuric acid. The quantity of copperas used is probably a little over a ton per week. The acid gas is discharged from a low chimney, at about the level of the public road (Station Bank). There would be no physical difficulty in condensing the fumes from this process.

Some nuisance arises from the discharge of smoke and imperfectly burnt gas, by the rather low chimneys of the annealing kilns in the Glass-works. This would be considerably ameliorated by the flues being led to a high chimney stalk, or might be entirely abolished were it found practicable to connect all the kilns with the gas-producers. In a town, however, where so much smoke and imperfectly consumed gases are given off—from brick-kilns and even from furnaces which might be wrought in a manner productive of little nuisance, it is perhaps invidious to particularize these Glass Works.

In the Tyne Flint Glass Works of Messrs. Moore & Co. articles for table use principally are manufactured. Mr. Moore declines to furnish me with precise information as to the constituents used in the production of glass in these works on the same grounds as the declinature of the Tyne Plate Glass Co. was based, but he informs me that—as in flint-glass works generally—the soda is used in the form of carbonate instead of sulphate, and hence no fumes are evolved in these works which can be productive of appreciable nuisance in the vicinity. The furnaces in use appear to be managed in such a way as not to give rise to complaint an the score of smoke nuisance.

In the South Shields Bottle Works ware of such fine quality not being required, the ingredients used in the glass-founding are much courser. The
Some complaints, however, have been made as to the quantity of smoke discharged from the cones of these works from time to time. This might be considerably mitigated if not abolished by the introduction of a special smoke-consuming apparatus, such as—for example—Frisbie’s Patent which is in use at many glass-works, in which the fuel is introduced by an ingenious contrivance from below.

In the St. Hilda and the Maxwell Street Glass Works small flasks and medicine bottles chiefly are made. These works are of small size and the “metal” is made up principally of old and broken glass collected by marine store dealers and again melted down. In each there is only one furnace, and in these furnaces coke is the fuel used. In the annealing kilns a mixture of coke and coal is burnt. From the very limited amount of “chemicals” used in the process of fusion, and the extent to which coke constitutes the fuel burnt, these works do not appear to be obnoxious to the public health.

III.—GAS WORKS.

From the Gasworks no such acid vapours are discharged as are liable to escape from the Alkali works and Glassworks, and it is improbable that they exert any appreciable influence upon the public health. At certain stages of the processes carried on at such works, however, it is possible that nuisances may occur, and I think it is desirable that the Sanitary Authority should be informed as to the nature of those processes, and the points at which obnoxious eminations may arise.

As the Committee are doubtless aware the coal from which the gas is to be distilled is placed in closed retorts exposed to a very high temperature—in these works the temperature at which the retorts are wrought is about 2010°F. The retorts are set horizontally in “benches” in groups of seven around each furnace; each consists of a cylindrical fire-clay tube, diam. 16 inches, and they are so arranged that the hot air from the furnaces plays around them as it is led to the flues which in turn communicate with the chimney; when working properly the retorts attain a bright orange heat. Some of the retorts in use at these works are “through” retorts, that is open and capable of being carged at both ends,—these are 18ft. long; the “single” retorts are 10ft.
long. From the projecting mouth-piece of each retort the "ascension-pipe" rises, by it the gas generated in the retort is conveyed away. The fuel used in the furnaces is coke which is practically a smokeless fuel. The retorts are discharged and re-charged every six hours,—in the case of the through retorts simultaneously at each end. When the operation is to be performed—the retort-lids are removed, the coke residue from which the gas has been distilled is raked red-hot into iron barrows. The new charge of coal—generally about 4 cwt. is then rapidly shovelled in, and a ready-prepared luted lid is placed on the mouth of the retort and wedged tight. In the retort-house the most likely cause of nuisance is the charging of the retorts: I have timed the men employed in this operation and find that 1½ minutes are taken to charge a retort by the shovelling process, during this time a smoky tarry vapour is being given off. Mr. Warner the ingenious manager of these works has devised an apparatus which is in use in the Jarrow Gas Works by which each retort may be charged in a quarter of a minute: the introduction of such an apparatus into gasworks generally is a thing to be desired. In the quenching of the coke dense clouds of watery vapour are given off, which add considerably to the humidity of the local climate—this being especially appreciable in cold or wet weather, but it is difficult to see how it can be obviated.

The crude coal-gas passes over from the retort through the ascension-pipe into the hydraulic main—a large horizontal pipe which extends the whole length of the bench of retorts and collects the gas from the series: the main, being kept about half-full of condensed, chiefly tarry, matter, forms a trap or liquid valve to prevent the admixture of atmospheric air with the gas. From this the impure gas is led through a "scrubber" into the condensers—a series of vertical iron pipes, where it is exposed to the cooling influence of the air, and in these tarry matters are deposited, and part of the ammonia is condensed together with the watery vapour of the gas. From the condensers the gas passes to the "scrubbers"—small towers, 45ft. high, containing tiers of "herring-bone" boards, that is boards placed slantingly in reverse directions in alternate tiers: over these boards water or weak ammonical solution is allowed to trickle, and the remaining ammoniacal impurity of the gas is condensed, forming the "ammonical liquor" of gas-works. The gas has now been freed from tarry matters and ammonia—its chief remaining impurities are Carbonic Acid, Sulphuretted Hydrogen, and Bi-sulphide of Carbon. In these works slaked (but not wet) lime alone is employed for the removal of these impurities. The lime is placed in trays, over which the gas is caused to pass, arranged in a series of four closed iron vessels, the most saturated of those being thrown out of series from time to time—and refilled. The chemistry of the process is this: the lime with the carbonic acid and sulphuretted hydrogen forms respectively carbonate and sulphide of lime: the sulphide of lime (Ca S) unites with the bi-sulphide of carbon to form sulpho-carbonate of lime.
(Ca\(\text{S}_3\)). These purifiers for the most part of the year are abundantly sufficient for the purification of the gas, but it is somewhat doubtful if they are adequate to the demands made upon them in the dead of winter when the process of gas production is at its height, a recent analysis of the gas (December 1882,) having indicated "23.68 grains of sulphur per 100 cubic feet, and some sulphuretted hydrogen," any escape of gas at this time giving rise to an exceedingly abominable effluvium. The "spent lime" from the purifiers, containing these sulphur compounds and other impurities is apt when exposed to the air to become a source of nuisance. As Dr. Ballard remarks, "volatile sulphur compounds are the most offensive of all chemical inorganic effluvia, and a very little of them in the atmosphere goes a long way where stink is concerned." The spent lime from these works, amounting on an average to about 10 carts a week during the winter, is deposited at "the Lawe," in the vicinity of the Recreation Ground, the Gas Coy, paying a man a small sum to cover it at once. This is a somewhat objectionable arrangement and one which is likely to give rise to trouble in the future. When visited the very disgusting odour of carbon di-sulphide was disagreeably appreciable in the vicinity: a certain per centage of this however must be placed to the credit of the town refuse which is also somewhat unfortunately deposited at this spot. With regard to the bestowal of the spent-lime I would remark that it is somewhat difficult to see why the Alkali Co.'s should be compelled to carry their tank-waste to sea, while the Gas Co. are allowed to form a local deposit of very analogous composition. I shall return to the question of the disposal of the town refuse on another occasion.

In these works the manufacture of the Sulphate of Ammonia is also carried on. In this process the ammoniacal liquor is run into a boiler heated in the usual way; by the heat the most part of the ammonia in the form of carbonate and sulphide is driven off and is led to the "saturator" into which sulphuric acid is also conveyed: Sulphate of Ammonia is thus formed and carbonic acid and sulphuretted hydrogen are given off—these latter are collected by means of a hood placed over the saturator, and are led away to the flue from the furnaces of the retort-bench. It would be a better arrangement if the sulphuretted hydrogen were passed into one of the furnaces directly and burnt: it is true that discharged as it is from a high chimney it is not productive of any appreciable nuisance in the district, still it forms a contribution to the general contamination of the atmosphere.
In endeavouring to differentiate the influence (if any,) of the Chemical Works upon the health of the town I have been impressed from the first by the difficult nature of the inquiry. Arguments in sanitary matters are never susceptible of mathematical demonstration. So complicated are the sanitary relations in a highly civilized state of society such as ours and in the case of the more or less crowded populations of our large towns, so diverse are the influences warring against the public health—that it is difficult if not impossible to allocate to each its due part in the final result. And in a manufacturing district, such as for instance South Shields, the difficulty is at its maximum—the insanitary influences are so many, the contamination of the atmosphere springs from such various sources. It is so difficult also to estimate the bye-play among our working-class population of vicissitudes in manufacturing prosperity—the alternations of high wages and no wages at all—with the thriftlessness and careless habits of mind apt to be engendered thereby, these latter having a very real influence on sanitary conditions. In view of all this it is not perhaps surprising that very little has been attempted to be done in the way of investigation into the influence of Chemical Works on the public health: “guesses at truth” in this matter there have been many, but of detailed methodical inquiry carried out in a scientific spirit, in this country at least, I have not been able to find evidence of any with the exception of that carried out for the information of the Noxious Vapours Commission of 1876 by my predecessor Mr. Spear, now one of the Medical Inspectors of the Local Government Board. To this general remark I consider that a paper read by Dr. Lunge before the Newcastle-upon-Tyne Chemical Society in 1874, entitled “Contributions to Sanitary Statistics in connexion with Alkali Works,” does not constitute any real exception.

For the purpose of his inquiry Mr. Spear divided the town into three districts which he classed respectively as, I. exposed to the fumes of the Alkali Works; II. less exposed; III. not exposed. With this arrangement he calculated the death-rates for the year 1875—a. from all causes, b. from zymotic diseases, c. from inflammatory lung diseases, d. from phthisis, e. from scrofulous diseases of children and convulsions—in each division. To the results so obtained—though more carefully wrought out than any others with which I am acquainted—exception might perhaps be taken from the strictly scientific point of view, on the ground—first, that the figures are derived from the sanitary statistics of only one year—a method which sometimes proves misleading. Second, that the investigation was not sufficiently minute; the districts were too large, and thus there came to be included in the same division streets differing so widely in sanitary relations and social conditions as Wapping Street and Westhoe (III.), Wellington Terrace and Waterloo Vale (II.), East Holborn (Johnson’s Hill, Cone Street, &c,) and Frederick Street (I.). Again, a minor objection might be urged on the ground that the popu-
lation of the different divisions was “estimated” and not actually ascertained, and as all the statistics were calculated upon the basis of population any error in the estimation would vitiate the results under such heading.

On entering upon this inquiry I determined to eliminate as far as might be at all practicable all such sources of fallacy. With the object of obviating the first of the above stated difficulties I have taken the sanitary statistics of five years—the years 1878–82. It has been necessary for me in pursuing the investigation to go over the birth registers of the town for five years, the death registers for three—classifying the entries in each case according to the streets in which the occurrences took place, in the case of the deaths also classifying them according to age and disease. In view of the second difficulty, but also for the general sanitary-statistical purposes of the future, I have considered it desirable to break up the town into very much smaller divisions than had been adopted in connection with the sanitary statistics of the past. I am of opinion that so long as in towns areas of considerable size and occupied by populations under the most various sanitary conditions are taken as the bases for sanitary statistics, it will be impossible to make these statistics serve in any way as an analysis of sanitary conditions. I have therefore divided the town into 63 sanitary “sections”: the ideal unit of population for these sections I have taken as 1000—believing that that number furnishes a basis for annual statistics sufficiently large to avoid the fallacies appertaining to the manipulation of small numbers. I have not however set up that number as an arbitrary standard—I have not classed together streets in evidently different sanitary circumstances for the purpose of making up a population of 1000, indeed several of the sections have been allowed to fall considerably short of the ideal standard rather than group streets in an artificial manner. My effort has been to place together streets (terraces, courts, or “hills”) adjacent, and as far as possible in the same sanitary and social footing. In this classification I have been much aided by the local knowledge and experience of the Sanitary Inspector. The third objection, in so far as population has been made the basis of my investigation is nullified by the results of the street-by-street enumeration of the population which the Sanitary Authority empowered me to carry out and which has placed in my hands the exact population of each street in the town. The appearance of this report has been considerably delayed by my determination in its preparation to take advantage of the results of the census: the census proved to be a work of considerably greater difficulty than had been anticipated, and the working up of its results has added materially to the laboriousness of the inquiry.

Before proceeding to state the result of my statistical investigation I may be permitted to glance for a moment at some of the current ideas with regard to the influence of chemical works in a district upon public health.
The blighting effects of the acid fumes from, alkali and glass works on vegetation is very generally appreciated and probably over estimated. It is argued that an influence so detrimental to vegetable life must be more or less injurious to the health of susceptible subjects such as children and delicate adults. And there is no doubt that this reasoning is entitled to a certain consideration. As qualifying the argument, however, it must be remembered that animal life is possessed of a much greater power of accommodation to surrounding circumstances than is the case in the vegetable kingdom. Apart from any such direct effect, however, I am persuaded that the presence of pungent gases in the atmosphere to any appreciable extent will tend indirectly, at least, to the deterioration of the public health, because of the inevitable tendency it produces on the part of the community towards the heretical closure of widows and doors and the consequent limitation of that household ventilation which is so necessary for the public health. It has been argued however as a per contra that the presence of these antiseptic gases in the atmosphere “extirpates some of the microscopic germs floating in the air and thus mitigates the spread of zymotic diseases:” or, as it has been ironically put, that a normal constituent of the atmosphere had been originally omitted and that chemical works had arisen to supply the deficiency. This argument is however evidently fallacious, as in the degree of dilution in which these acid gases exist in the atmosphere even in the vicinity of alkali works they can have no real antiseptic power. Baxter, in the course of some experiments with sulphurous acid quoted by Professor Parkes, found that “with *58 per cent. (of sulphurous acid) the poison of infective inflammation was still active,” and of course the acid gases are not present in the atmosphere even in the immediate vicinity of alkali works in anything like that proportion. The fact of the exceptionally severe visitation of South Shields by small pox in 1871 (in which year about 4000 people, or nearly one-tenth of the population, were attacked by the disease) indeed creates a large presumption against the idea of the anti-zymotic influence of chemical works.

For the purposes of this inquiry I have taken as an area more particularly exposed to the fumes from alkali works sixteen streets situated in close proximity to the Tyne Alkali Works—all of them with the exception of a small part of one (Maxwell Street) within a radius of 1000 feet from the works,†

* Chemical works situated in manufacturing districts must not be credited with anything like the total injury which falls upon plants and trees in the neighbourhood: there is no doubt that the extensive consumption of coal and consequent production of sulphuric acid gas materially contributes to the same results.

† These streets are Albert Terrace, Charlotte Terrace, Claypath Lane, Cuthbert St., Derby St., Derby Terrace, Edward St., George St., Martin St., Maxwell St., Pallister St., Peel St., Percy St., Smith St., Sunny Terrace, Wilson St.—these streets may be taken as a fair average of the streets in which the mass of the population is aggregated, and considerably above the level (from the general sanitary point of view) of the Holborns—Waterloo Vale—and the “Low” part of the town.
and comprising in all a population of 4548—a sufficiently large number especially when a quinquennial period of observation is taken. The Tyne Alkali Works is exceedingly well adapted to the purposes of the inquiry: the populations in the immediate proximity of the other alkali works and to the Tyne Plate Glass Works are too small to enable me to make them the basis of a detailed investigation. In order to make a satisfactory and thorough analysis of the sanitary condition of this “exposed” district I have classified the deaths occurring therein during the last five years and calculated the general death-rate, the proportion of deaths of children under one year to the total number of births, and the proportion respectively of deaths of children under five, deaths from zymotic diseases, deaths from phthisis, and deaths from inflammatory lung diseases—to the total deaths. A similar series of calculations has been made for each of the sixty-three sections into which the town has been divided; and the results obtained in connection with the “exposed division” have been compared with the means and with those of the individual sections. The results brought out by these calculations are not striking—the scientific mind is disposed now-a-days to receive “striking” results in matters sanitary with some scepticism; but I think, having been attained by much pains-taking labour and with much care to avoid sources of fallacy, that they form a contribution of some value to a scientific settlement of the question of the influence of chemical works on the public health. I may remark here that it is evident that the results would have been more decisive if the streets included in the “exposed divisions” had been excluded from the individual sections, and still more so if the influence on the other sections of the other chemical works could have been eliminated.

1st. General deathrate.—I found after a little consideration that it would be fallacious to base the calculation of the deathrate of the sections for the quinquennial period on the population as now ascertained—from the fluctuations in the population and the number of new houses constantly being put in occupation all over the town: I have therefore taken the deathrate for only the last year, 1882. I find that in the selection of streets which I have styled “the exposed division” the death rate was 23.7, the mean deathrate of the town in the same period was 20.8—the deathrate of the exp. div. was thus 2.5 above the mean, otherwise stated—41 sections of the town had a lower deathrate than the exp. div.* I should however lay little stress on these figures, applying as they do to only one year, were not their tenor supported by others which follow.

2nd. Infantile Mortality.—The deaths of children under one year old calculated on the number of births during the quinquennial period 1878-82 indicates in the exp. div. a rate of 16.9 per cent., the mean of the sections

* The detailed figures for each section will be found in the Annual Health Report for 1882.
was 14·2—the rate in the exp. div. was thus 2·7 above the mean, otherwise stated—47 of the 63 sections of the town had a lower rate of infantile mortality. The infantile mortality is usually considered the most delicate test of the sanitary condition of a locality, and the one least open to fallacy.

3rd. Percentage of deaths of children under five years old, calculated on the total deaths—five years 1878-82.—In the exp. div. 60·5, the mean of the sections generally was 49·1—excess in the exp. div. 11·4. 53 of the 63 sections of the town had a lower deathrate.

4th. Percentage of Zymotic deaths to total deaths, 1878-82.—In the exp. div. 21·5, the mean of the sections was 19·6—excess in exp. div. 1·9. 41 sections had a lower Zymotic rate.

5th. Percentage of deaths from Phthisis to total deaths, 1878-82.—In exp. div. 6·0, in the sections generally the mean was 8·8—excess of sections generally over exp. div. 2·8. Only 20 of the 63 sections had a lower deathrate from Phthisis.

6th. Percentage of deaths from Inflammatory Lung Diseases to total deaths, 1878-82.—In exp. div. 19·0—mean of sections 17·1—excess in exp. div. 1·9 42 sections had lower deathrates from pulmonary diseases.

The most salient points brought out by these figures as regards the district particularly exposed to the fumes from the alkali works are, 1. The generally higher deathrate. 2. The excessive mortality of children under five years of age. 3. The fact that there is no diminution in the zymotic rate. 4. The appreciably lowered deathrate from consumption—this latter is more clearly brought out when stated as—that the phthisical percentage under the mean was 46 per cent. of the total phthisical percentage \( \frac{218}{50} \times 100 \). 5. The slightly heightened pulmonary rate.

After so lengthy a report any elaborate periscript would be out of place. I think it right however before concluding to express my sense of the courtesy with which my visits to the various chemical works in town have been received, and the evident wish which has always been exhibited by the managers to reduce to a minimize any offence to the public apt to arise out of the processes carried on in these works.