ON THE MODE OF STATEMENT OF THE RESULTS OF WATER ANALYSIS AND THE FORMATION OF A NUMERICAL SCALE FOR THE VALUATION OF THE IMPURITIES IN DRINKING WATERS.

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A GREAT deal has been written about the analysis of drinking water, but in my opinion, the ground is by no means entirely covered, and although I am prepared to expect a difference of opinion on some of the points I am about to bring forward, I think it will be admitted that most of them are to some extent at least new. Samples of drinking water come into the hands of analysts, probably in larger numbers than samples of any other article used for food or drink, and yet we find, that while, as regards a sample of milk, or oil cake, or bread, the statement of the results obtained is made by most analysts in a somewhat uniform style, when we come to water, scarcely two analysts will be found who will express the results obtained from the analysis of a given sample, or the deductions from those results in the same way.

One of the earliest attempts to which I need refer at systematizing the methods of water analysis was made in 1865 by Dr. Miller, the then President of the Chemical Society, but his paper went very little further than carefully detailing the systems and the processes to be adopted for the determination of the various constituents which were then usually determined in the process of a full water analysis, and although Dr. Miller unquestionably did good service in some ways by his paper, he was also probably the first to lay the foundation of the objectionable system which has since sprung up of reporting the results of water analyses in foreign instead of English measures. It may be that through his position as one of the Royal Commissioners of weights and measures, Dr. Miller became more deeply imbued with the *supposed* advantages of the foreign metrical system over the English system, but, at any rate, although he did not go so far as to advise that the reports of water analyses should be made entirely in foreign measure, he did advise what it is pretty certain no analyst would ever think of carrying out, viz.:—that duplicate reports should be sent in, one in English weights and measures and the other in the foreign system,—thus duplicating the work of writing the report and turning the analyst into a feeble parody of a popular teacher.

Dr. Miller's suggestions bore their full weight however, and consequently we find that he was followed not long after, first by Frankland and Armstrong, and then by Wanklyn, Chapman, and Smith, who were the next workers in the field of water analysis, and who both adopted, one fully, and the other in part, the metrical system. On this point my opinion is very strongly in favour of the adoption of the English weights and measures only. Water analyses are ordinarily made not for the information of analysts or scientists, but for the guidance of the public, and especially for those members of the public who have in their official capacity to arrange for the water supply of the people. To any of these persons who are of ordinary average intelligence, a gallon is a quantity of which they have to some considerable extent a fairly accurate conception, and I think, that to the majority of them, a drop and a grain would be viewed as very nearly synonymous terms. They have therefore a true mental conception of what are the units of volume and weight, in which the results of the analyses are expressed, and are therefore able to form some idea on their own account of what degree of impurity is indicated by a certain given figure, say for instance, 5 grains of salt per gallon.

On the other hand I have never yet met with an Englishman of ordinary average intelligence who, unless he had given some special attention to the study of science, could form the remotest idea of the quantity or weight represented by a litre or a milligram. I will go still further, and say that, as regards the unfortunate notation of parts per million, it has not yet fallen to my lot to meet with any Englishman (myself not excepted) who could form a fair mental conception of what a million really is. I am aware that it will be urged against my arguments that the reports of analysts are made to stand as permanent records for the guidance of future analysts, but to that I reply that, should the metrical system be so far advanced in the 20th century as to be generally adopted, trained analysts will then be as readily able to translate the grains per gallon of the 19th century into the milligram per litre, or parts per million, or whatever other denomination may by that time have been invented, as we are to-day able to translate Frankland's or Wanklyn's statements into grains per gallon.

If the advocates of the metrical system of weights and measures should so far succeed as ultimately to get that system adopted in this country, then by all means let analyses be reported according to it, but until it is so adopted—not merely, as at present, optionally (which option is never exercised), but as a matter of necessity—I think the report should be made in such a way that a person of ordinary intelligence has a fair opportunity of understanding what the statements mean.

I am also aware that it may be urged by some that the processes of analysis are simplified by the adoption of the metrical system, but I dissent from this. In my own Laboratory I use and recognize no other unit of weight than a grain, and in an analysis of water no other unit of measure, than the decimal parts of a gallon. The grain, as a unit of weight, cannot, at any rate, be simplified, and the measure of 1-10th, 1-100th, or 1-1000th of a gallon is not worthy to be called a complication. I therefore express my opinion most decidedly in favour of the adoption of the system of grains and gallons only, for reporting the results of water analyses.

Having now referred to the figures which I think should be employed to report the results in, I come to consider what results should be reported, and this naturally resolves itself into the question of whether the Frankland process or the Wanklyn process should be followed, and whether either of these processes should be supplemented by means of other determinations. It is to be noticed that in both cases the latter part of the instructions for carrying out these rival processes, contain full details for sundry other determinations than the organic carbon and nitrogen, and previous sewage contamination, which are the bases of the Frankland process, and the albuminoid ammonia, which is the basis of the Wanklyn process; but it is not by any means clear in what way these supplemental determinations are to be used or considered in appraising the results of the analyses.

Let us see first what are the objections to each of these processes. First, as regards the Frankland process, the personal equation or amount of experimental error involved in working the process is so excessively great that an allowance amounting to more than the degree of impurity present in ordinary drinking water has to be made before the results can be even *supposed* to be correct. No doubt it is extremely easy to make a few blank experiments and to deduct a constant found by these, from the impurities found in the course of a water analysis, but, in my opinion, a constant found in this way is not either identical or fairly comparable with the constant which really

occurs when a water residue is treated—that is the two constants are obtained under different conditions, and therefore are not directly comparable with each other, and as a necessary consequence the deduction made by those who use the Frankland process is only by accident an accurate one. If my view on this point is right it is clear that all attempt to rely upon the determination of organic carbon and nitrogen as an indication of present sewage contamination, even when the process is carried out by a skilful manipulator, must be useless; but we have, in addition, to bear in mind that the manipulation involved in the process is so difficult and tedious that, although the process has been before the public for ten years, viz., since 1868, it would hardly be possible to find ten analysts in the United Kingdom who regularly use it.

I pass now to the Wanklyn process—this certainly possesses the advantage of extreme simplicity, and with the slightest care in manipulation, it is also accurate, *i.e.*, it gives uniform results from the same samples provided it is analyzed while moderately fresh. There are, however, one or two defects in the determination of albuminoid ammonia which are not always sufficiently considered, among these is that urea—which, if not the most dangerous, will be admitted to be one of the most significant indicators of impurity—is not detected by it, and that some of the other nitrogenous compounds, which are quite likely to occur as occasional impurities in drinking water, yield up their nitrogen in the form of albuminoid ammonia in such an irregular proportion that the difficulty of forming a judgment from this one estimation only is considerably increased. So while I still consider that the determination of albuminoid ammonia, according to Wanklyn's process, is the most important and the most valuable determination in the whole analysis, I do not assent to the extreme weight or value (practically excluding all other determinations) which is now placed upon it by its inventors. Wanklyn, in the preface to the fourth edition of his treatise on Water Analysis, says that he is “now prepared to trust to a direct test for the actual presence or absence of organic matter, and can afford to discard indirect and in many instances delusive signs.” Carrying this statement to the extreme, we make a *reductio ad absurdum* of it, for we find that if 20 grains of urea were present in a gallon of water the sample would still be passed as absolutely pure.

I think, therefore, that this determination of albuminoid ammonia, valuable as it is, as indicating present contamination, in the form of a very large number of nitrogenous compounds, must be supplemented by determinations which show also whether there has been previous contamination, or, in other words, what nitrogen in other forms is present. I do not view the estimation of nitrates, to quote Wanklyn's words again, “as a step in the exhaustive mineral analysis of a water residue,” but I view it as essential in the analysis of a water for ordinary potable purposes. This, therefore, raises the whole question of what are the determinations necessary, and here I take what seems to me the plainest and most common-sense view of the matter when I state that the report should specify every determination which has been made in the analysis of the water, and that the opinion given upon the water should be based upon the deductions drawn from *every one* of those determinations. If an opinion is given upon determinations which are not specified in the report itself it is very possible that some analyst at a future time may be misled, as I was not long since by a report which stated that a water only contained 17 grains of total solid matter, and was therefore quite free from organic impurity. If a determination is worth making at all it is

worth writing, and if it is worth writing it certainly ought to be worth consideration of some kind in forming an opinion on the results—if this is not the case time has been wasted in making it. For instance, if it is worth determining the salt, it must be because salt in some proportion or other, may be a deleterious constituent in water, and therefore in deciding what general report should be given upon the water in question due weight (whatever that may be) should be given to the proportion of salt found to be present; and again, if it is worth while to determine hardness, it must be because hardness, in some proportion or other, is injurious, and due weight should be given to this point also.

Therefore I think that, not only should all the figures be stated in the report, but that the statement should be made to assume a uniform style, and that due weight should be given to every figure in the analysis.

In drawing the inferences both Frankland and Wanklyn have, to *some* extent but not fully, adopted this view, for when we look to the original instructions for the Frankland process, or the amended instructions contained in the latest edition of Sutton's volumetric analysis, or when we take the 4th edition of Wanklyn's Treatise on Water Analysis, we find instructions for a considerable number of other determinations, beyond those which are distinctly included in the figures upon which Frankland and Wanklyn respectively base their opinion as to the character of the water. Thus, for instance, Wanklyn is quite prepared to trust to albuminoid ammonia only, yet he gives full instructions for the determinations of salt, hardness, and numerous other constituents, and Frankland bases his opinion of present contamination upon organic nitrogen and carbon only, yet he also gives rules for the determination of salt, hardness and other constituents. Both however are alike, as far as I know at present, in giving absolutely no instructions whatever for what I consider one of the most important points, namely, a microscopical examination. It is clear that Dr. Frankland does not think this unnecessary, because, in his reports on the water supply of the metropolis, we frequently find reference to the living organisms which, by the aid of the microscope, he has found in water, but whether these living organisms are those which may strictly be called microscopic, or whether they belong to that larger class which may be detected by a good pocket lens, I am not able to say.

Having so far pointed out the difference of opinion which I hold from the statements of the inventors of these two processes, I will next point out what I do really consider essential. I think the determination of total solids is essential, because they may be so heavy as to be sufficient to condemn a water, and I certainly have a statement by Wanklyn in favour of this opinion: for he says, "unless the water contains more than 40 grs. of total solids per gallon no exception need be taken to the total solids as such." If these words mean anything at all, they mean that 40 grs. and upwards of total solids are injurious to the character of the water. I carry it further still, and say that I prefer to have a water like that of Loch Katrine rather than that supplied by the Kent Company, and, therefore, I give a certain, and, in my opinion, due weight, to the proportion of total solids per gallon contained in the water. I also think it necessary to determine the volatile matter, or loss on ignition, and here I differ entirely from both Frankland and Wanklyn, although I am in accord with Miller, who says that an error of weighing in this case is one of the most important errors in the whole analysis. Again, I think it necessary to make a determination of the amount of salt, and Miller, Frankland, and Wanklyn, all think so as well, but none of them seem to place any

special value upon the determination when it has been made. The nearest reference to it that I can call to mind now is in the Fourth Edition of Wanklyn's book, p. 15, where he says, "It occasionally happens that the finding of a little or no chlorine in water is a valuable criterion of purity." I would only alter this sentence by substituting "always" for "occasionally." On the next page he says, "When water is found to contain much chlorine, there is reason for suspecting the presence of sewage." I quite agree with this, and therefore I consider it essential to give a distinct value to every unit of chlorine in the form of chlorides which the water contains. I think, too, the hardness should be determined, because independently of the mere waste of soap which is incurred by the use of hard water, those who have (as I unfortunately have) daily experience in the use of an objectionably hard water, are well aware of the unpleasant sensations produced in washing with it, and of the great difficulty of making tea or coffee, or similar infusions of an equally palatable quality to those which can be obtained from a soft water. The free ammonia should also be determined, and in this respect I agree with both Frankland and Wanklyn; but, unfortunately, the latter's statement in reference to it appears in such an obscure manner on p. 40 of his Fourth Edition, that it would be frequently overlooked, although, as I think, it is one of the most important statements in the book. He says, "when the free ammonia exceeds .08 parts per million, it almost invariably proceeds from the formation of urea into carbonate of ammonia, and is a sign that the water in question consists of diluted urine in a very recent condition." I can scarcely think of any words to condemn a water more strongly than those I have quoted. "*Diluted urine in a very recent condition*" must be one of the very worst waters which can possibly be used for drinking purposes. Therefore I have Wanklyn's authority to confirm me in putting a certain definite value upon the free ammonia present. I also determine the nitrates and nitrites, and consider these determinations necessary, because they are, to a very great extent, an index, although *not an accurate measure* of the *previous* contamination of the water. Nitrites are, of course, worse than nitrates, because the oxidation has not proceeded so far; but in either case these so-called mineral salts have organic origin, and, therefore, they are proof of contamination, which, although it is not exactly dangerous at the time the sample is being examined, shows that at some time contamination has occurred, and where it *has* occurred, it may recur again at any time.* The estimation of oxygen absorbed by organic matter from a solution of permanganate of potash comes very much in the same category. Water which is thoroughly oxidised, and, therefore, fairly freed from deleterious substances in an active form, will decolourise only a very small portion of permanganate solution, and I think there can be no question on the part of anyone who has been in the habit of working with this solution on a variety of samples of

* Mr. Stoddart, of Bristol, writes in reference to the water supply of that place that it is brought 20 miles from the Mendip hills, that there is no possibility of sewage contamination, that it is brought in closed iron pipes into a very large reservoir, which is made of limestone, and slopes very considerably. There are no bacteria or animalculæ whatever that he has seen, but it is a very good collecting ground for diatomaceæ; when the sides of the reservoir get dry the diatoms die and furnish a large quantity of ammonia, which give rise of course to nitrates; many a time when he has made a good collection of diatomaceæ in a small bottle he had not had time to look at them when he reached home, and had consequently put them aside till the next day, when the ammoniacal smell was so abominable and just like animal matter that sometimes he thought it was a misnomer to call them vegetable. The only fault of the supply is that it is not perfectly filtered and free from minute portions of the dead diatoms. All the nitrates are solely derived from the dead diatoms.

water, that it does form a very fair and reasonable test as to the amount of organic impurity present. I quite agree with the remark Miller makes in reference to it, that as a substitute it is probably useless, but that as an accessory it does good service.

Passing now from the strictly chemical results, it is quite possible to meet with samples of water, and I have in fact seen several such, which contain so much recent urine that the urea, and in some cases the urate of potash, can be distinguished by the microscope in the residue left by the evaporation of one or two drops. It is obvious that such waters as these are totally unfit for human consumption, and yet the albuminoid ammonia would fail to detect this impurity: the oxygen absorbed would indicate it in part only, and the free ammonia to an even less extent; while I apprehend that there is hardly any chemist who would object to the statement that living organisms of any kind whatever, and all growths of the bacteria class, are injurious; and yet the microscope, and that alone is the only means by which these impurities can be detected. I consider that no sample of water should be passed as good unless it has been microscopically examined, and this examination should be credited with its due weight in the report, and, if necessary, the water should be condemned on the result of that examination alone.

Taste and smell also afford valuable indications when they are taken in the proper way. Not long since I analysed a sample of water which was in almost every respect chemically satisfactory, and it showed no objectionable features under the microscope, but when it was slightly warmed and the smell ascertained by drawing air through a tube, the walls of which were moistened with it, there was such an offensive odour of sulphuretted hydrogen as to fully account for all the complaints which had been made about it. Surely then this is enough to condemn a water upon. I condemned this water without any hesitation, and yet the albuminoid ammonia was low. Nor is this offensive smell of sulphuretted hydrogen confined to this particular sample, for some of the deep well chalk waters, which are taken by Frankland as a standard of purity, and in which the nitrates are ignored by those who report simply according to the albuminoid ammonia, contain enough sulphate of lime and organic matter to cause decomposition to set up, and a distinct smell of sulphuretted hydrogen is produced when the water has been standing in a cistern for twelve or twenty-four hours. I have known cases too, and that not a few, where the determination of colour is of value. I am quite aware that a difference of opinion prevails as to whether peaty matter is objectionable; my opinion is that it is. I think the gathering grounds should be free from peat as well as from other impurities, and probably no other test so readily recognizes the presence of peat as the colour of the water when seen through a stratum of 2-ft. deep.

I think there are cases where the determination of magnesia and the alkalies and phosphoric acid may be necessary, but these cases occur comparatively seldom, and the determinations, on account of the small quantities present, are attended with so much difficulty and uncertainty that for the present I omit them from my remarks.

Summing up the whole, therefore, I consider it necessary in every case to determine the total solids, loss on ignition after deducting combined carbonic acid, hardness before and after boiling, chlorine calculated as chloride of sodium, nitrogen in the four forms of free ammonia, albuminoid ammonia, nitrates and nitrites, oxygen absorbed by organic matter, colour in 2-ft. tube, taste and smell when warmed, and the absence or presence of suspended matter, and also to examine the residue microscopically. If these results show

a doubtful character in the water, I think it necessary to consider the results of Heisch's sugar test, so as to get a confirmation or otherwise of my opinion on the other results, but this examination should be made while the sample is fresh.

Of course I am quite aware that a complete investigation of this kind renders it quite impracticable to analyse waters for a guinea, but I confess that I have no regret on this point, as I think it is very much better, both for the public and the analyst, to have one sample thoroughly examined and fully reported upon in a report which shall have a reliable basis, than to have half a dozen samples analysed and reported upon with so few determinations made that the opinions given are unsatisfactory.

Having pointed out what determinations I make, the next question is how to appraise or estimate each of them at its true value. Of course the difficulty of doing this is considerable, but having once granted that these determinations are desirable, and also that, if a determination is desirable and has been made, some weight should be given to it in the calculations of the results, the matter is somewhat simplified. The first mode, according to which a scale of this kind can be formed, is to consider what amount of any one of the constituents shown by the analytical figures already referred to would be sufficient to keep the water from ranking as first class, supposing that all the other constituents were of a fairly satisfactory character, or, to put it in another way, supposing that the ammonia, albuminoid ammonia, nitrates and nitrites, were all good, what amount of total solids would condemn the water and relegate it to the second class; or supposing that the total solids were also good, what amount of salt would be sufficient to lower its rank. I take this as the starting point for the formation of a valuation scale, and I think we may say that 75 grains of total solids per gallon, or 15 grains of loss on ignition after carbonic acid has been deducted, or 15 grains of salt, or .015 of a grain of albuminoid ammonia, or 1.5 grains of nitrogen as nitrates (equal to nearly 10 grains of nitrate of soda per gallon,) or .15 of a grain of oxygen absorbed from permanganate, should each be held to be decidedly objectionable chemical characteristics, while as to the physical ones I think that a water which has a urine yellow colour when viewed through a tube two feet long, or which has a decidedly offensive taste or smell of sulphuretted hydrogen, or which shows any traces of copper, or when examined by the microscope shows fungoid growths, or a large proportion of peaty matter, should also be considered as lower than first class. Therefore, here we have the basis of a valuation scale for reports on water analysis.

Of course what I have said at present relates simply to the ratios which subsist between the different constituents, but it is perfectly clear that we must take some definite figure as the basis upon which to calculate these ratios. Now I have come to the conclusion that the easiest mode of forming this scale is to adopt the smallest basis of measurement as the unit of the scale, therefore as I consider that albuminoid ammonia is the most injurious factor in the analysis, and that .001 of a grain per gallon of that constituent is probably the most minute measurement to which it is really necessary to carry the valuation at present, I consider that .001 of a grain per gallon of albuminoid ammonia is equal to 1 degree of impurity; nitrogen in the form of nitrites takes rank next because it indicates that some organic matter has become converted into so-called mineral nitrogenous compounds, but yet has not been fully oxidized; still I view nitrogen when present in this form as of only half the importance or value that I do when it is present in the form of albuminoid ammonia. I therefore estimate

that .002 of nitrogen as nitrites equals 1 degree of impurity. Next I rank the oxygen absorbed by organic matter, and here, though I am quite aware that it will be one of the most disputed points in the whole scale, I have assumed that .01 equals 1 degree of impurity, *i.e.*, I estimate oxygen absorbed at 1/10th of the value I give to the albuminoid ammonia. Free ammonia comes next, and considering that it may be derived and frequently is derived from other sources than the decomposition of urea I value this at one-half the value I give to oxygen absorbed, that is .02 of free ammonia is equal to 1 degree of impurity. Nitrogen as nitrates is of course far less important, and I estimate this at 1/5th of the value of free ammonia, so that .100 of nitrogen as nitrates equals 1 degree of impurity.

Leaving the nitro-compounds I come to the general mineral constituents of the analysis, and here I have not only valued the total solids, but also to some, although to a different extent, the constituents of which these total solids consist, that is for every 5 grains of total solids, I allow a definite value of 1; for every 1 grain of loss on ignition, carbonic acid being deducted, I give a definite value of 1, as I also do to every 1 grain of salt, and I add together the hardness before and after boiling, and for every 5 degrees of the total hardness so obtained I count 1. This amounts to the same thing as giving a value of 1 to every 5 degrees of temporary hardness, and a value of 2 to every 5 degrees of permanent hardness. For traces of copper or traces of lead, both of which, however minute, I consider are exceedingly objectionable characteristics in drinking water, I allow a value of 6.

Passing now from the strictly chemical tests to the physical ones, I class a good taste as 0; a taste of decaying leaves or flat rain water as 2, while for more offensive tastes still, I allow higher values up to 10. For a yellow green colour, giving decided indications of either vegetable or urinary contamination or both, I allow a value of 4; for a full urine yellow, 6, and the values of the microscopical results range from 3, for the presence of a few bacteria, up to 12, for a residue full of animal organic remains, and even as high as 18 where urea and muscular fibre can be detected in the dried residue of a few drops.

From my remarks further on it will be evident as regards the physical as distinguished from the chemical tests, that these values must at present be viewed as an outline only, because the intermediate numbers have to be filled up. It is extremely difficult to discriminate in mere words between the different gradations of smell, taste, and microscopic appearance. But taken as an outline the table stands this way:—

5 grs. total solids	1	Taste, decidedly offensive	6
1 gr. loss on ignition	1	Smell, flat rain water	2
1 gr. chlorine calculated as chloride of sodium	1	Ditto urine	6
.0200 gr. free ammonia	1	Colour, pale yellow	2
.0010 gr. albuminoid ammonia	1	Ditto yellow green	4
.1000 gr. nitrates	1	Ditto urine yellow	6
.0020 gr. nitrites	1	Ditto opaque yellow in 2-ft. tube	9
.0100 gr. oxygen absorbed	1	Microscope, bacteria	3
5 degrees total hardness	1	Ditto, other similar growths in greater quantity	4
Traces of lead	6	Ditto, few living organisms	6
Ditto copper	6	Ditto, animal remains	12
Heisch's sugar test	6	Ditto, urea and urates and muscular fibre... ..	18
Taste, good	0	Suspended matter, traces	2
Ditto, slightly saline	1	Ditto heavy	4
Ditto, decayed leaves	2		
Ditto, flat rain water	2		

The question now arises how does this scale work out, and where are the limits of purity fairly to be drawn upon ordinary waters. I reply, it is only by undertaking, as I have recently done, the somewhat difficult task of sorting nearly 200 waters in as far as could be an approximate order of merit, that it is possible to answer this question, and I have come to the general conclusion that a valuation falling below 35 may be taken to

indicate a first-class water, to which no exception can fairly be taken; that a valuation of between 35 and 55 may be taken as a 2nd class water; and one between 55 and 75 as a third class water which is of a suspiciously dangerous character, while those samples which give a higher value than 75 should be considered as waters of such a dangerously contaminated character that they can only rank as sewage. To take a comparatively familiar illustration of the first class waters. The ordinary supplies of the London water companies, when in good condition, will show a value on this scale generally ranging between 15 and 22.

As regards the chemical results obtained, it is evident from what I have said, that all analysts who adopt this scale would agree in the calculation of the results, but a certain difficulty, and by no means an inconsiderable one, arises when we come to the physical tests. Every analyst is able to make an accurate determination of 5 grains of total solid matter per gallon, but it is extremely difficult for me to convey to others, or for others to understand from me what I mean by a flat or an offensive smell. At present I am hardly able to bring forward such illustrations as I should wish on the matter, but I am endeavouring to make standard solutions which shall serve as representations of the numbers or values which I attach in my scale to smell, colour, and taste. The microscope will then be the main point on which a true difference of opinion may exist, which will of course lead to a difference of valuation. I scarcely know in what way this difficulty is best to be overcome, but should the suggestions I am making, and the scale I am proposing, meet with fair acceptance at the hands of the analysts generally, I should have great pleasure in attempting to prepare a series of say 3 or 4 different slides, giving actual microscopical illustrations of what I understand by the numbers in my scale. As regards urea and such salts there is no difficulty, for of course a standard solution can be made to which a certain amount of sulphate of lime and salt, and other ordinary constituents of drinking water, may be added, but as regards the confervoid and other growths, and animalcule, it is evident that no plan can be adopted but the preparation of a standard set of slides. If I can succeed in this as I hope, the valuation will then so far be strictly comparable with a standard, and will be free from every trace of personal equation or personal bias.

It is right now that I should give some illustrations of these figures and the analyses of some few samples, and showing the manner in which this valuation works, the figures are those of actual analyses recently made. The figures are grains per gallon.

No.	1	2	3	4	5	6
Total Solids	5.00	25.50	6.12	228.80	103.80	141.80
Volatile matter	0.95	0.25	1.92	3.68	11.30	28.50
Chlorine calculated as Chloride of Sodium	0.94	3.51	2.00	182.87	29.07	59.67
Hardness before boiling	0.88	13.28	1.98	20.8°	36°	528
Ditto after boiling	0.78	2.48	1.98	7.2°	19°	428
Nitrogen as free ammonia	0.0030	0.0025	0.0118	0.0020	0.0029	0.0291
Ditto as albuminoid ammonia	0.0020	0.0030	0.0102	0.0024	0.0270	0.0158
Ditto as Nitrates	0.0240	0.0700	0.0670	0.7696	4.1300	5.4604
Ditto as Nitrites	0.0043	trace	0.0030	0.0058	0.0040	0.0064
Total combined Nitrogen	0.0333	0.0755	0.0920	0.7798	4.1639	5.5117
Oxygen absorbed	0.0300	trace	0.0240	0.1085	0.0540	0.1200
Suspended matter	trace	none	trace	trace	none	heavy
Colour	pale blue	pale blue	—	fair	{ dirty opaque yellow	urine yellow
Smell	satisfactory	good	—	„	„	fair
Taste	fair	„	—	briny	„	saline
Microscope	{ amorphous & rootlets	satis- factory	satis- factory	earthy matters	unsatis- factory	satis- factory
Lead and Copper	none	none	none	none	none	none
Iron	none	trace	trace	trace	trace	heavy
Value according to my scale	12	14	24	185	159	256

The best water in the above series is, in my opinion, the No. 1 sample, and on looking through the figures it will be seen that there are only five lines in which a higher value than one is given to any determination. Nitrogen, as albuminoid ammonia, showing $\cdot 062$ ranks as 2; oxygen absorbed ranks as 3; suspended matter ranks as 2, the taste which is flat like rain water is also 2, and the microscope, which shows amorphous sedimentary matter and rootlets but no animal matter, ranks as 2. I may take next the case of No. 2, which is another good water, and here the total solids value at 5, the salt 3, double hardness 3, albuminoid ammonia 3, while the physical tests are all so satisfactory that there is no addition to be made for any of them. As the next illustration I may take No. 3. Here we have a rather large proportion of albuminoid ammonia, namely, $\cdot 0102$, this amount being heavier than often occurs in first class water, yet when the other figures are viewed, and especially the low proportions of total solids and salt, the softness and the entire absence of unsatisfactory physical characteristics, it is not surprising that the value of the water is as low as 24.

Passing now to one or two cases where the proportions of impurity are larger still. Nos. 4 and 5 will illustrate the scale very well. In the No. 4 sample the albuminoid ammonia was only $\cdot 0024$, and the only objectionable physical characteristic was the presence of earthy matter, shown by the microscope, but the chemical tests disclosed the presence of $182\cdot 87$ grains of chlorine calculated as chloride of sodium, per gallon, and combined with this there is a considerable proportion of nitrogen as nitrates, and the valuation therefore runs up to 185. This sample consequently ranks as unmistakable sewage, despite the low albuminoid ammonia. We have another illustration in No. 5, where the albuminoid ammonia is high enough to already condemn the sample, even if no other determination were made, that is, this factor is 11 times as high as in the last sample referred to; but this sample being considerably less saline, the valuation of it, although still placing it in the sewage class, is somewhat lower than No. 4.

In No. 6 we have a still heavier valuation. Here also the albuminoid ammonia is so high that the water would have passed as third class on that alone, but when other circumstances are taken into account, the condemnation is proved to be still greater, and the water ranks as one of the very worst I have seen for a long time. Thus it contains $28\frac{1}{2}$ grains of volatile matter, nearly 60 grains of salt, the permanent hardness is 42, and the nitrogen as nitrates is $5\cdot 46$ grains per gallon. This water affords a very good illustration of the fact, that although in some cases it may appear that I have placed an undue value on physical tests, yet that on the whole, my scale must be a fair approximation to the truth, for in this water I find that the smell was fair, the microscopical results satisfactory, the taste saline, which of course must be expected, the colour was only a pale yellow, and the only really unsatisfactory physical determination was that there was a considerable quantity of suspended matter. This water therefore takes worst rank without the physical tests having any particular weight.

I think I have now explained as fully as space will permit, the scheme I propose for the valuation of drinking waters, and the manner in which I think the results should be stated, and I invite the criticisms, not only of the members of this Society, but of all analysts on the proposals. It must be borne in mind in the discussion, that I do not propose any new methods or new processes. I think the discussion would be far better not complicated by any extraneous matters of that kind at present, I am simply considering the recognized determinations and methods, and the deductions which should be drawn from them, and the modes in which they should be stated.

The first question asked will naturally be:—What do I claim for this scale? My reply is a far better method of estimating or valuing the relative degrees of impurities in water than has hitherto been proposed. I do not claim that at present the scale is perfect in all its figures. I am quite aware that difference of opinion may, and to some extent must exist, as to the relative importance to be attached to some of the determinations in question, and these are points which are fairly open to argument, and which I should like to discuss so as to make the scale one which can be uniformly adopted; but while admitting that some of the figures are open to discussion, I claim that the broad fact, that every determination made should be stated and should be taken into account, is one which lies at the very foundation of any system of forming an accurate opinion upon the character of a water.

In the discussion which took place:—

Dr. Bartlett said he thought the plan Mr. Wigner had adopted was an excellent one, but the valuations were of course to be discussed, as that was one of the main issues. He should take exception to the salt in moderate quantity being considered as a measure of sewage impurities. Many waters originally pure contain large quantities of chloride of sodium or other alkaline earths, and he believed there was no objection to a water containing a moderate proportion of salt, but he declined to discuss then the question of how much was wholesome or unwholesome, but there would be no objection to a pure water containing 20 to 30 grains per gallon, but when we come to 185 grains that is different. He found Mr. Wigner had not estimated the SO_3 , which he (Dr. Bartlett) considered a very objectionable element in drinking water,—especially sulphates of lime and magnesia. Mr. Wigner said he intended to give illustrations of bad smells, and he (Dr. Bartlett) was curious to know how he would do it, but he thought there should be plus and minus signs, so that waters which were moderately objectionable might be excused by reason of their being in some other respects good. He had always condemned waters which had an unpleasant smell. He also had had waters which, according to the Frankland and Wanklyn methods were pure, with a very small amount of total solids, and yet they came from medical men who attributed illness to a slight smell and a slight peaty colour. One water was analysed nine times, and nothing found except a smell of sulphuretted hydrogen, and a peaty colour, and yet this water was almost conclusively proved to have caused illness.

Mr. Hehner did not know why Mr. Wigner objected so much to the metrical system, he did not suppose Mr. Wigner reported the analyses of sugar in grains per gallon but in percentages, and therefore to report water in parts per million would be only carrying it one step further. He did not think urea and urates could be present in such large quantities that they could be determined; the presence of fœces would be much more objectionable than urea or urates. If the sulphates were determined, and very little found, it would be clear that as urine contains a very large amount of sulphates, the chlorine did not come from urine.

Dr. Dupré said there was little doubt but that Mr. Wigner had begun the right way in stating that everything that was worth determining was worth giving a certain weight to. As to the valuation he thought there ought to be some squares and cubes, so that the figures should not be simply multiplied, but increased in a greater ratio. He was quite sure that nitrates in a deep well water ought not to be put on the same footing as nitrates in a shallow well; in the one case it is an impurity almost harmless, but in the case of a

shallow well it is different. And the same remark would hold good to a great extent with ammonia, which, however, is not found in such large quantities. As to potash and soda, the determination of the relative proportions of the chlorides might show whether the contamination was of human or animal origin, and this is important, because human beings are not so liable to catch disease from an animal, whereas the urine from a human being is much more likely to cause disease.

In reply, Mr. Wigner pointed out that an indirect value was given to sulphates, inasmuch as permanent hardness was in the majority of cases a fair measure of their amount, and this, by the scale adopted, was valued twice as high as temporary hardness. The plan proposed by Dr. Bartlett, of passing salt or other impurities up to a certain point as harmless, appeared to him wrong. Small quantities of salt *may be* of minor importance, but if so, and the scale is wrong, let it be altered. The first rule should be to give a certain condemning influence to *every* impurity. Mr. Wigner considered Mr. Hehner's remark, comparing percentages with parts per million, rather an unfair comparison, because every man of common sense could grasp the 100 parts, whereas no fair conception could be formed of a million units. The difficulty was increased just ten thousand-fold. As to Dr. Dupré's remarks he (Mr. Wigner) considered there was force in what he said as to the increasing values as the proportion increase, but unless an exhaustive examination of the well had been made he could not assent to give a lower value to nitrates in a deep well water than in a shallow well water, because deep wells were in very many cases contaminated with surface drainage. In illustration of this Mr. Wigner pointed out that in the 6th Report of the Rivers Pollution Commission it was stated that out of "21 samples of water from indisputably unpolluted sources" only two were condemned, and these were both from St. Boniface's Wishing Well. But anyone who knew this well and St. Boniface Down as thoroughly as he did, would immediately find the cause of the pollution to arise from a large natural hollow on the surface of the down where the droppings of cattle pastured on the Down gradually accumulated and were washed down by the collected rain, which really formed the true supply of the "Wishing Well." The rain soaked through so rapidly that there was a great increase in the flow of the well so soon as one hour after rain. Therefore this "unpolluted source" was really a polluted one.

ADDITIONAL NOTE ON THE ABOVE SUBJECT—

I think there is considerable weight in the remarks made after the reading of my paper by Dr. Dupré, as to the desirability of an increasing scale of value when certain figures in the analysis are excessive. The effect which this alteration was intended by Dr. Dupré to have was to render certain high values of certain constituents absolutely prohibitory by ensuring the condemnation of the sample. I think this result will be very readily achieved by a slight modification of the scale. It will be seen by an examination of the specimen analyses (and perhaps still better by the application of the scale to other *complete* analyses already available), that a water of even passably good quality will rarely show any single determination in the analysis of a value so high as 10. Therefore if the simple rule is taken of doubling the excess of value over 10 attached to any single determination, the scale will not be any more stringent as regards the pure waters, while it would be a stronger condemnation of the impure ones.

It would act in this way, if the albuminoid ammonia in a sample is .009 grains per gallon it would value as 9. If it were .014 the excess above .010 would be valued at the doubled ratio, and we should consequently have $.010 = 10 + .004 = 8$, total 18; similarly if the nitrogen as nitrates were 1.000 grains, the value would be 10, but if the constituent were present in the proportion of 2.000 grains, the excess proportion would be doubled in importance, and the value would be 30. I think this modification will improve the scale without greatly complicating it.

G. W. W.

PUBLIC ANALYSTS' WORK DURING 1877.

IN reply to the request contained in our last number we have received a large number of returns from various public analysts, but we are unable at present to give a tabulated statement of the number of samples examined, &c., as the list is not complete. We therefore again call the attention of those gentlemen who have not yet sent us in their returns, and we trust they will kindly favour us with them by the 20th instant, in order that our table may be as complete as possible.