V. VON REIS' METHOD.

In the *Zeitschrift für angewandte Chemie*, *1890*, appears an article by M. A. von Reis and F. Wiggert on the determination of cobalt in the volumetric way.

The cobalt solution is treated with an emulsion of zinc oxide and brought to boiling, when a known quantity of a standardized solution of potassium permanganate is added.

The oxidized cobalt falls to the bottom and allows of the back-titration of the potassium permanganate by ferrous ammonium sulphate.

	Cobalt present. Gram.	Cobalt found. Gram.	Percentage.
1	0.1334	0.1330	99.70
2	0.1334	0.1325	99.32
3	0.1334	0.1328	99.55
4	0.1334	0.1334	100.00
5	0.1334	0.1340	100.45

To all appearances this is by far the most satisfactory method yet proposed. Its simplicity recommends it.

CONCLUSION.

After careful repetition of these methods, making varying conditions wherever deemed advisable, one is justified in concluding that none of them possess the degree of accuracy required in any trustworthy determination of cobalt. A good volumetric method for this purpose still remains to be devised.

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RECENT WORK IN ENGLAND ON THE PURIFICATION OF SEWAGE.[1]

By LEONARD P. KINNICUTT.

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THERE are few questions connected with municipal government which cause as much trouble as the disposal of sewage in such a manner as to prevent any cause for complaint, and it is certainly not far from the truth to say that, at the present time, there is no large inland city in the world that has succeeded in satisfactorily disposing of the refuse matter that passes through the sewers.

[1] Read at the Washington Meeting, December 29, 1897.

The three methods used for the purification of sewage are: irrigation, or sewage farming; chemical precipitation; and intermittent filtration.

The first two methods have been tried by many large cities, and opinions differ as to their comparative merits. The history of sewage disposal is evidence of this difference of opinion.

There are in Great Britain forty-three cities which have a population of over 70,000. Direct information from personal investigation shows that, in 1897, twenty-one of these cities discharged their sewage practically untreated into tidal rivers, or into the sea: Liverpool, Edinburgh, Dublin, Belfast, Bristol, Newcastle, Hull, Portsmouth, Dundee, Cardiff, Oldham, Sunderland, Aberdeen, Brighton, Birkenhead, Swansea, Gateshead, Plymouth, South Shields, Middleborough, Cork, and Stockport; nine used chemical precipitation as a means of purification: London, Glasgow, Leeds, Sheffield, Bradford, Salford, Bolton, Huddesfield, and Southampton; two, chemical precipitation, allowing the effluent to pass over a small area of land: Manchester, 30 acres, and Burmley, 30 acres; five, broad irrigation: Leicester, Blackburn, Norwich, Preston, and Walsall; two, broad irrigation preceded by chemical precipitation: Birmingham and Wolverhampton; one used chemical precipitation for a portion of the sewage and broad irrigation for the remainder: Rochdale, chemical precipitation with 250,000 gallons and broad irrigation with 1,000,000 gallons. Of the German cities containing over 70,000 inhabitants, only Berlin, Breslau, Madgeburg, Frankfort, Danzig, Charlottenburg, Braunschweig, Halle, and Essen treat the sewage. Frankfort, Halle, and Essen by chemical precipitation, the other cities by broad irrigation, Berlin using for the purpose 14,473 acres and having in reserve 6,737 acres.

In all these cities there is great difficulty in obtaining satisfactory results. Those cities using broad irrigation find that more and more land must be added to the so-called sewage farm to prevent the drainage from causing a nuisance, and in those cities where the chemical precipitation method is employed, there is no doubt that there has been great difficulty in obtaining sufficient purification, especially when the surrounding district is extensively occupied, and where there is no large watercourse to carry away the purified effluent. The question, therefore, that is now engaging the attention of sanitary engineers is, can that third process, intermittent filtration, be substituted in place of the other two?

The work that has been carried on at the Lawrence Experiment Station in regard to this third method of purification, is too well-known to all interested in the subject for me to dwell upon it, and I think it is only necessary to state that the experiments there carried out have shown that 100.000 gallons of crude sewage per day can be purified in the spring, summer, and autumn months by allowing it to filter through one acre of prepared sand filter-beds, underdrained at a depth of from three to five feet. In winter, however, where the filter-beds are unprotected from frost, snow, and ice, according to my observations, very much more than one acre of land is required for each 100,000 gallons. The top layer of sand becomes covered with a layer of what might be called *papier-mâché*, varying from one-eighth of an inch to almost a half inch in thickness. The formation of this layer is due to the finely divided paper in the sewage, and it is almost impervious to water. During the warm months, this coating is prevented from forming, by raking over the surface of the beds each week or two, but between the middle of November till the last of March in the cities of Massachusetts, this cannot be done and, as a rule, they are left untouched during this time. The rate of filtration gradually grows less and less, and from what I have seen at Gardner, Marlboro, Brockton, Framingham, and Westboro, I believe that twice, at least, and possibly four times as much area is required in winter as in summer.

This is a most serious defect in the process of intermittent filtration as recommended by the State Board of Health, of Massachusetts, and any improvement in the process which will partially obviate or remove this difficulty, either by reducing the amount of filtering surface required, so that covered beds could be used, or by preventing the finely ground paper from coming in contact with the filter-beds, so that the *papier-mâché* coating would not form, would be of great value. Such being the case I have been much interested in the recent developments in sewage treatment made in England, especially in the work of Dibden's bacteria filter now in use at Sutton, and in Cameron's septic tank, now being tried at Exeter. Before speaking of these methods, however, I would like to say a word in regard to the filtering material used in Great Britain. Here sand is almost universally employed, there, on account of the difficulty of procuring sand of the desired quality, various other substances have been tried, burnt clay, or clay ballast, coke, breeze, cinders, clinkers, finely divided coal, etc., and it has been found that any jagged, porous substance is well fitted for the purpose, though curiously enough, experiments seem to show that either fine coal or fine cinders, are, on the whole, the best.

Regarding the special work that I have mentioned, Dibden's bacteria is the outcome of experiments made at Barking on the effluent of London sewage, the sewage itself being chemically treated with lime and iron sulphate.

In making the filtering at Barking the drains had been so arranged that by closing the valve of the main underdrain, the sewage could be kept in the bed for any number of hours, and a series of experiments were made with the view of ascertaining what would be the result of allowing the sewage to remain in the filter for a varying number of hours before passing it into the underdrains, the idea being that the work of purification was not limited to the surface, but took place throughout the body of the filter, and that a greater amount of purification could be obtained by filling the filter and allowing it to stand full for a certain length of time, thus giving the micro-organisms in the center and at the bottom of the bed the same amount of work to do as those nearer the surface, than by allowing the sewage merely to drain slowly through it. The method of working the bed was as follows:

The underdrains being closed, the filter was filled with dilute sewage which was allowed to remain in it for two hours; the drains then being opened, the purified sewage was allowed to run off, air being drawn into the filter as the effluent ran out, the whole cycle requiring seven hours. The filling, standing, and emptying was constantly repeated for six days, when the work was stopped for twenty-four hours to allow of further aeration. The results obtained were most satisfactory. Running at the rate of 500,000 gallons per day, the albuminoid ammonia was reduced from 0.712 part in 100,000 to 0.162, showing a purification equal to seventy-eight per cent. Running at the rate of 1,000,000 gallons per day, the purification, measured in the same way, equaled sixty-six per cent.

When both the amount treated and the percentage of purification are taken into account, this result is surprisingly good; yet the chief difference between these experiments and those that had been previously made, was that the whole of the filtering material was brought into intimate contact with the organic substance of the dilute sewage and allowed to remain in contact with it for a definite time, thus making full use of the cubical capacity of the filter.

The use in this way of the whole cubical capacity of the filter was new, and although it is only three years since these experiments were made, many sanitary engineers now claim that the cubical capacity of a filter should be taken into consideration in determining its purifying power and not only its superficial area, as has been the case. Therefore, instead of saying that one acre of filtering material three feet deep is capable of purifying so many hundred thousand gallons of sewage, one should say that the purification could be accomplished by 130,680 cubic feet of filtering material. Taking into account the depth of the filter as well as its area, is most important, for it leads to the possibility of purifying large amounts of sewage on comparatively small areas. The depth of the filter, however, must necessarily be limited to the point to which the air can be carried down in sufficient quantities for successful aeration, and as yet a sufficient number of experiments have not been made to decide how deep air can thus be carried, though undoubtedly the depth will be found to depend more or less on the filtering material that is used.

Sutton is the first town to attempt purifying its crude sewage by the above method, and as the plant is under the direction of Mr. Dibden and Mr. Thudicum, a detailed description of the filter and the results obtained, gathered by a personal visit to the works, may be of interest.

The population draining into the sewers is about 13,000, and the dry weather flow equals about 400,000 gallons per day. The sewage system is on the "separate" plan, rainfall being excluded, yet during wet weather a large volume of subsoil water gains access to the sewers. The town contains few, if any, manufacturing establishments, and the sewage may be considered as a strong domestic sewage.

Sutton formerly purified its sewage by the use of chemicals and one of the precipitating tanks was utilized for the construction of a filter. On the floor of the tank, whose area was 183 square yards, was laid a six-inch drain, connected with nineteen lateral drains three inches in diameter. The main drain was provided with a six-inch valve so that the filter could be emptied or filled at will. The pipes were covered with very coarse, burnt clay, and upon this was placed a layer of burnt clay three feet deep, the smallest pieces of which could not pass through a half-inch mesh. The total capacity of this filter was 218 cubic yards, and when filled with burnt clay it would hold 13,500 gallons.

The crude sewage, after passing through iron screens to intercept large pieces of paper, is carried directly to the filter, the flow being stopped as soon as the sewage level reaches within an inch or so of the burnt clay. The time required for filling the filter is about one hour. The filter is allowed to remain full for about two hours, and then emptied, the time occupied in emptying it being one and one-half hours. The filter is then allowed to rest for two hours after which it is again charged. The effluent obtained is clear and without any strong odor, and appears to the eye equal to the best effluent obtained by the chemical precipitation process. From analyses made three or four times each month, from November, 1896, to June, 1897, and published in the *Surveyor* for July 9, 1897, the amount of purification as calculated from the albuminoid ammonia equals about fifty-eight per cent., while the amount of suspended matter is reduced from fifty to two and three-tenths grains per gallon.

The work of the filter compares favorably with the results obtained by many of the chemical precipitation processes, and, though twelve months is possibly too short a period from which to draw conclusions, the city is now constructing three more bacteria filters, and there seems to be no question that the above method leads one to entertain the view that with domestic sewage a purification equal to that obtained by chemical precipitation is possible with comparatively small, artificially prepared filters ; and from experiments which are now being made, it seems possible that some similar plan can be used with the sewage of a manufacturing city.

The effluent obtained by the bacteria filter when running at the rate of 1,000,000 gallons per acre, is not sufficiently pure to drain into a water-course, whose volume only equals or is less than the volume of the effluent, and when the stream runs through a thickly populated district as is the case in Sutton, and, consequently, there the first effluent is run through another filter of the same size and construction, filled however with burnt clay, all of which is small enough to pass through a half-inch mesh. The effluent from this second filter, at the time of my visit, was bright, clear, and without odor. The average amount of albuminoid ammonia in this effluent during the seven months from November to June was 0.243 part in 100,000 parts, the original sewage containing 1,130 parts, and the amount of suspended matter was reduced to 0.703 grain per gallon.

These results are certainly most interesting and instructive, and show what advance is being made in the process of purifying sewage by means of those micro-organisms which fulfil their life-functions in the presence of oxygen. Still more interesting than the bacteria filter on account of its being an entirely new departure, is the septic tank system of purification introduced by Donald Cameron, of Exeter, England. It has long been known that in the decomposition of organic matter by micro-organisms not a single species, but many species are at work and that they could roughly be divided into two classes : the putrefactive bacteria, those which live in the absence of light and oxygen and exercise a reducing or deoxidizing action, and those organisms whose life depends on the presence of oxygen and are known as the nitrifying bacteria. Mr. Cameron's septic tank treatment is based on the idea that the decomposition of organic matter is more easily and rapidly accomplished if the deoxidizing bacteria are allowed to do their work before the organic matter comes in contact with the nitrifying organisms. This is, of course, contrary to the commonly accepted idea that sewage is best treated before putrefaction begins, yet there is much to be said in favor of Mr. Cameron's plan. To separate the two kinds of action the sewage is first led into a large tank, vaulted so as to exclude light and air, and is allowed to remain in this tank till putrefaction has taken place, when the sewage is passed upon the filter-beds which contain, as all filter-beds do, the nitrifying organisms. This method of treatment has been introduced into Exeter, England, and at present about 70,000 gallons are being treated each day.

The plant consists of the so-called septic tank, which is an underground tank built of cement concrete, sixty-four feet long, eighteen feet wide, and of an average depth of seven feet, having a capacity of about 53,000 gallons and of five filters made of coke breeze and furnace clinkers, about five feet in depth and covering all together an area of 400 square yards, having a capacity of 695 cubic yards. The crude sewage as it arrives at the plant passes through a railing to prevent large objects from entering the tank, while all small particles and solids in suspension pass freely to a grit chamber which is divided in two, each part having an inlet into the tank. The inlets are close to the bottom of the tank and the aperture of the inlet pipes is smaller on the tank side than on the sewer side, so that the sewage enters the tank with considerable force. The outlets are also beneath the surface of the water so as not to admit air or light, and so arranged that the water at the middle depth alone escapes. They are gauged so that the rate of flow may be measured; usually it is about 3,000 gallons per hour. The sewage from the septic tank is discharged simultaneously on two of the bacteria filters arranged according to Dibden's method. When these two filters are full they are emptied of their contents, and, while being emptied, the sewage from the tank passes on to others. The fifth filter remains idle one week, when it takes the place of the one that has longest been in use. Thus each filter remains idle one week out of every four. The filling and emptying of these filters is done automatically by an ingenious arrangement patented by Mr. Cameron and is said to be most satisfactory.

The action inside the tank is essentially of a putrefactive nature, no nitrates being formed. The organic matter is decomposed, or rather broken up into simpler forms, a large amount being rendered soluble, while at the same time ammonia and, I believe, free nitrogen are being formed. According to analyses made by Dibden, the amount of oxidizable organic matter in solution is reduced about 30.8 per cent., the free ammonia about 26.9 per cent., the albuminoid ammonia about 17 per cent., and the suspended solids about 55 per cent. Pearmain and Moor, who have made a report on the process, state that there is no accumulation of sludge in the tank beyond a small amount of thin black sediment, which they report is so slight that a year's accumulation would scarcely be worth the trouble of removing. F. J. Commin, in a report on the process published in the *Lancet* for December, *1896*, says that the deposit is very fine and inorganic, and that in a small tank after seven months' continual working and after quite 2,000,000 gallons of sewage had passed through the tank, the deposit was less than four inches over a surface of twenty-four feet by nine feet.

On top of the liquid in the tank there is a layer of flocculent matter from two to two and one-half inches in thickness, and from all accounts this seems to have been formed during the first few weeks that the tank was used and not to have increased much in thickness since that time. It appears to be composed of organic matter, formed I believe from the suspended matter in the sewage, and from all the information I have been able to obtain, it seems as though the organic matter in this flocculent layer was at first partially decomposed by the putrefactive organisms. Portions of it then sank to the bottom of the tank, where further action took place. Bubbles of gas collected around the fragments that had been carried down, causing them to rise to the surface and this process went on till the residue that remained at the bottom contained very little organic decomposable matter.

This action reminds one of what takes place in small streams into which sewage is emptied. I have often seen in such streams cakes of at least one-half yard in circumference rise from the mud at the bottom, and float down with the current.

According to Dibden the liquid that comes from the tank is of a brownish yellow color, offensive, and contains 2.73 grains per gallon of free ammonia, 0.175 grain of albuminoid ammonia, and the amount of oxygen absorbed from potassium permanganate in four hours is 1.405 grains per gallon. It contains no nitrates nor nitrites. The original sewage contained at the same time 3.778 grains free ammonia, 0.212 grain albuminoid ammonia, and the oxygen absorbed from the potassium permanganate was 2.028 grains per gallon. This liquid is passed upon the filters as has been described and the effluent from these filters contains 1.705 grains free ammonia, 0.078 grain albuminoid ammonia, 0.253 grain nitrogen as nitrites, 0.353 grain nitrogen as nitrates, no suspended matter, and the absorbed oxygen from the potassium permanganate in four hours is only 0.388 grain per gallon.

The great advantage of the septic tank process, if it does what it appears to do, is that so large an amount of suspended matter is removed from the sewage that there will be very much less trouble with the clogging up of the surface of filter-beds in winter, and consequently an area that is large enough for the purification in summer will be more nearly, or possibly quite, sufficient for the work during the winter months.

It is also claimed that a large amount of the organic matter in solution is removed in the septic tank and if this is so, which appears probable from the analyses that have been made, it may not be too much to hope that future developments in this direction taken in connection with the using of the cubical capacity of a bacteria filter, may so reduce the area required for purification, that filter-beds may, without too great expense, be protected from snow and ice.

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INVESTIGATION OF THE THEORY OF SOLUBILITY EFFECT IN THE CASE OF TRI-IONIC SALTS.

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THE theory of the effect of salts on the solubility of one another has, in the case of di-ionic salts having one ion in common, been quite thoroughly tested and confirmed.[1] The solubility of tri-ionic salts in the presence of other salts, however, has been much less investigated. The theory of the phenomenon has, to be sure, been already developed, and has been partially tested by experiments with lead chloride in the presence of other salts.[2]

[1] Compare especially Noyes and Abbot : *Ztschr. phys. Chem.*, 16, 125.
[2] Noyes : *Ibid.* 9, 626.