A CHEMICAL, BIOLOGICAL AND EXPERIMENTAL INQUIRY INTO THE PRESENT AND PROPOSED FUTURE WATER SUPPLY OF THE CITY OF ALBANY.

By Dr. Albert R. Leeds.

In the Spring of the present year, the Legislature of the State of New York was moved, by the frequent outbursts of popular indignation in Albany, with regard to the quality of its water supply, to create a Special Water Commission. And, inasmuch, as the investigations which I found necessary to make, as chemist to this commission, caused me to travel over certain new ground, I have thought it might prove of interest to the profession to put certain of the results on record in this journal. Fortunately the wording of the Act appointing the commission not only gave, but also encouraged considerable latitude of inquiry, for it directed that two objects should be kept in view :—

1st. Due inquiry into the available sources of supply of pure and wholesome water.

2d. If the present water supply proved on investigation to be the best available, then as to what, if any, method could be adopted for its improvement, or if possible, its purification.

In the conduct of the first branch of the investigation, I had occasion to examine the following possible sources of supply :—

1st. Certain lakes and water courses east of the Hudson, but in the immediate vicinity of Albany.

2d. Driven wells on the hills west of Albany, and driven wells located upon the flats lying along the river, north and south of the city.

3d. Various points upon the Hudson River, such as Waterford, situated above the influx of sewage from the city of Troy, and as many other points between Troy and Albany as would be necessary to investigate the question of the self-purification of the stream and the advisability of shifting the location of the mouth of the intake of the present pumping station to such other point as might be shown to afford better water.

4th. The Mohawk River above and below the falls.

With regard to the second branch of the inquiry, I was authorized by the commission to institute experiments upon the relative advantages of the following methods :—

1st. Purification by artificial oxidation by gaseous oxidants, and more specially oxygen, air and ozone, at ordinary atmospheric pressures and temperatures, or at increased pressures and temperatures.

2d. Purification by the use of solid substances, acting either as oxidants or precipitants or both.

3d. Combinations of the two preceding, in various orders and under various conditions of temperature and pressure.

4th. Purification by natural and artificial filtration, according to the many methods either hitherto in use, or such as might prove themselves peculiarly adapted to the environment of the Albany water supply.

5th. Combinations of the first three, or purification proper, with the fourth, the object being primarily to render innocuous noxious matter, both such as exists diffused in a state of solution, and particulate in the form of micro organisms ; and secondarily, to remove the *débris* of this noxious matter, and all suspended substances as well, by effective filtration.

In the conduct of the experiments falling under the five heads above enumerated, I was prevented by the necessity of performing a great number of analyses upon the various proposed sources of supply, and the limited time allowed by the Legislature to the commission before bringing in its final report, from prosecuting them to the desired point. I am able, therefore, to give only certain results in this place, and shall postpone the presentation of the remainder until they are worked out in connection with the proposed new water supply of the city of Philadelphia.

The methods of investigation made use of in connection with the Albany water supply, might be summarized under three classes :

A. Analytical.
B. Experimental.
C. Biological.

I. Analytical Data.

The analytical data established in the case of each sample, were the free and albuminoid ammonia, the nitrous and nitric acid, the oxygen required to oxidize organic matters as determined by permanganate at the boiling point, and also by means of photochemical measurement, chlorine, hardness, total solids dried at 110°, fixed matter at low redness, volatile matter at low redness, and the dissolved oxygen, carbon dioxide, and nitrogen gases. The nitric acid was determined by reduction to nitric oxide and endiometric measurement of the evolved gas. The original method for photo-chemical measurement of the oxygen required to oxidize organic matter, as stated in *The Philosophical Magazine*, has been modified in its application to more than 500 samples of waters, and the improved method and results I hope to find leisure to communicate in a subsequent article, together with the apparatus employed for the endiometric measurement of dissolved gases.

In the five tables which follow, are given :

I. A comparison of the waters of certain lakes and streams of the hill country east of the Hudson River, with the water taken from the Hudson at the present Albany pumping station. This comparison was made in deference to the opinions of those who thought that waters taken from elevated points in a mountainous district must necessarily be purer than that taken from a great stream flowing at a lower level.

II. Comparison of the water from a number of driven wells located on the hills west of Albany, and upon the alluvial flats lying along the Hudson River immediately north of the city, with the waters of the Hudson River.

III. A comparison of the waters of the Hudson River itself from a point above the influx of the sewage of Troy to the Albany pumping station, a distance of about seven miles.

IV. A comparison of the waters of the Mohawk River above and below the falls with those of the Hudson River taken directly at the intake, as delivered directly from the faucet at the City Hall, and as delivered from a commercial sand and charcoal filter located at the same point.

V. A comparison of the mineral constituents in the waters taken from two mountain lakes, a mountain stream, and a driven well in the hill country, with the waters of the Hudson River and the Mohawk River.

TABLE I.—LAKES IN RENSSELAER COUNTY WITH ALBANY PUMPING STATION FOR COMPARISON.

Laboratory Number	826	827	828	829	830	837
Special Number	I.	II.	III.	IV.	V.	VI.
Location	Snyder's Lake—Middle.	Sand Lake—Middle.	Poestenkill River at East Poestenkill.	Dykeing Pond.	Pump-well of Pumping Station at Albany.	Pump-well of Pumping Station at Albany.
Date	Sept. 4th.	Sept. 4th.	Sept. 4th.	Sept. 5th.	Sept. 5th.	Sept. 16th.
Color	0	0	1.25	1.75	4.00	2.00
Taste	Earthy.	Slight.	Peaty.	Slightly marshy	Pleasant.	Pleasant.
Smell	None.	None.	Peaty.	None.	Faint.	Slight.
FREE AMMONIA—						
Parts per 100,000	0.002	0.009	0.011	0.014	0.004	0.011
Grains per gallon	0.0012	0.0052	0.0061	0.0082	0.0023	0.0064
ALBUMINOID AMMONIA—						
Parts per 100,000	0.037	0.029	0.032	0.026	0.019	0.023
Grains per gallon	0.0215	0.0169	0.0186	0.0152	0.0111	0.0134
NITROUS ACID—						
Parts per 100,000	None.	None.	None.	Trace.	Trace.	None.
Grains per gallon	None.	None.	None.	Trace.	Trace.	None.
NITRIC ACID—						
Parts per 100,000	0.147	0.189	0.27	0.90	0.147	0.09
Grains per gallon	0.0857	0.11	0.157	0.524	0.0857	0.052
OXYGEN REQUIRED TO OXIDIZE ORGANIC MATTERS [PERMANGANATE]—						
Parts per 100,000	0.32	0.25	1.90	0.60	1.20	0.74
Grains per gallon	0.1866	0.145	1.108	0.35	0.70	0.43
OXYGEN REQUIRED TO OXIDIZE ORGANIC MATTERS [SILVER]—						
Parts per 100,000	0.49	0.32	0.85	0.75	0.56	0.523
Grains per gallon	0.285	0.187	0.496	0.437	0.326	0.301
CHLORINE—						
Parts per 100,000	0.30	0.21	0.34	0.34	0.35	0.375
Grains per gallon	0.175	0.122	0.198	0.198	0.204	0.218
HARDNESS—						
Parts per 100,000	3.7	2.3	1.80	2.50	4.8	4.7
Grains per gallon	2.15	1.34	1.05	1.45	2.8	2.74
TOTAL SOLIDS—						
Parts per 100,000	7.40	3.7	5.5	6.90	10.7	11.0
Grains per gallon	4.315	2.157	3.2	4.02	6.23	6.41
MINERAL MATTER—						
Parts per 100,000	3.70	2.0	1.5	1.60	7.9	7.0
Grains per gallon	2.157	1.166	0.874	0.933	4.6	4.08
ORGANIC AND VOLATILE MATTER—						
Parts per 100,000	3.70	1.70	4.0	5.3	2.8	4.0
Grains per gallon	2.157	0.99	2.33	3.09	1.63	2.33
DISSOLVED GASES BY VOLUME—						
Oxygen, cubic centimeters per liter	5.02	5.57	5.55	3.96	5.24	3.83
Carbonic dioxide, cubic centimeters per liter	1.48	1.61	0.86	6.56	1.29	2.72
Nitrogen " " "	12.20	12.02	12.59	12.02	12.22	12.58
Total Gases, cubic centimeters per liter	18.70	19.20	19.00	22.54	18.75	19.07

Laboratory Number	838	868	869	871	872	870
Special Number	VII.	VIII.	IX.	X.	XI.	XII.
Location	Well on Blessing Farm.	Well No. 1 on Three Hill Farm	Well No. 2, on Three Hill Farm	Well on Flats, Troy Road.	Well No. 5, on Dr. T. Helmes' Farm.	Pump Well of Alb'nyPumping Station.
Date	Sept. 17th.	Oct. 19th.	Oct. 19th.	Oct. 29th.	Oct. 19th.	Oct. 19th.
Color	0.5	0.25	0	2.0	0	2.0
Taste	Unpleasant.	Pleasant.	Pleasant.	Pleasant.	Pleasant.	Pleasant.
Smell	None.	None.	Slightly vegtble	Slightly Unplnt	None.	Slightly Unplnt
Free Ammonia—						
Parts per 100,000	0.013	0.012	0.017	0.002	0.024	0.004
Grains per gallon	0.0076	0.007	0.01	0.0012	0.014	0.0023
Albuminoid Ammonia—						
Parts per 100,000	0.011	0.015	0.01	0.011	0.01	0.017
Grains per gallon	0.0064	0.0087	0.0058	0.0064	0.0058	0.01
Nitrous Acid—						
Parts per 100,000	None.	None.	None.	None.	None.	None.
Grains per gallon	None.	None.	None.	None.	None.	None.
Nitric Acid—						
Parts per 100,000	0.20	0.09	0.09	0.088	0.1	0.15
Grains per gallon	0.1166	0.052	0.052	0.0512	0.058	0.087
Oxygen Required to Oxydize Organic Matter [Permanganate]—						
Parts per 100,000	0.034	0.15	0.095	0.12	0.10	0.71
Grains per gallon	0.0198	0.087	0.055	0.07	0.058	0.41
Oxygen Required to Oxydize Organic Matter [Silver]—						
Parts per 100,000	0.523	0.41	0.52	0.37	0.56	0.57
Grains per gallon	0.304	0.238	0.302	0.215	0.326	0.332
Chlorine—						
Parts per 100,000	2.95	3.0	3.25	0.525	2.000	5.25
Grains per gallon	1.72	1.75	1.90	0.305	1.166	3.05
Hardness—						
Parts per 100,000	10.30	11.0	11.10	11.95	2.50	8.29
Grains per gallon	6.00	6.41	6.45	6.96	1.45	4.83
Total Solids—						
Parts per 100,000	20.9	20.25	21.3	22.9	19.5	12.0
Grains per gallon	12.18	11.81	12.4	13 4	11.37	7.0
Mineral Matter—						
Parts per 100,000	18.0	17.5	18.0	20.6	18.3	9.0
Grains per gallon	10.5	10.2	10.5	12.0	10.6	5 24
Organic and Volatile Matter—						
Parts per 100,000	2.9	2.75	3.3	2.3	1.2	3.0
Grains per gallon	1.69	1.60	1.92	1.34	0.7	1.75
Dissolved Gases by Volume—						
Oxygen, cubic centimeters per liter	4.17	2.53	2.79	3.05	2.44	4.45
Carbon dioxide, cubic centimeters per liter	1.54	1.14	1.09	4.18	4.40	2.28
Nitrogen " " "	12.54	14.95	16.26	19.50	15.75	12.92
T Gases, cubic centimeters per liter	18.25	18.62	20.14	26.73	22.59	19.65

TABLE III.—HUDSON RIVER FROM WATERFORD, ABOVE TROY, TO ALBANY PUMPING STATION.

Laboratory Number	850	851	852	853	854	855	857	856
Special Number	XIII.	XIV.	XV.	XVI.	XVII.	XVIII.	XIX.	XX.
Location	Waterford, middle of river, 2 feet below surface.	Troy Pumping Station, 2 feet below surface.	River one mile below Troy (opposite Roy's Factory), 6 feet below surface.	River two miles below Troy (opposite Catholic Church), 6 feet below surface.	River three miles below Troy (above Pleasure Island) 6 feet below surface.	1,400 feet above Albany Intake (opposite Forbes' Mansion), 6 feet below surface.	1,400 feet above Albany Intake (opposite Forbes' Mansion), 6 feet below surface.	Intake of Albany Pumping Station, 6 feet below surface.
Date	Sept. 29th.	Sept. 29th.	Sept. 29th.	Sept. 29th.	Sept. 29th.	Sept. 29th.	Sept. 29th.	Sept. 29th.
Color	1.0	1.25	1.25	1.0	1.0	1.0	1.0	1.0
Taste	Slightly peaty.	Slightly peaty.	Slightly peaty.	Slightly peaty.	Peaty.	Slightly peaty.	Slightly peaty.	Slightly unplnt.
Smell	Slightly unplnt.	Slightly unplnt.	Slightly unplnt.	Slightly Unplnt	Unpleasant.	Slightly unplnt.	Slightly unplnt.	" "
Free Ammonia—								
Parts per 100,000	0.003	0.003	0.003	0.002	0.002	0.0025	0.0025	0.003
Grains per gallon	0.0018	0.0018	0.0018	0.0012	0.0012	0.0015	0.0015	0.0018
Albuminoid Ammonia—								
Parts per 100,000	0.015	0.015	0.015	0.015	0.018	0.013	0.015	0.014
Grains per gallon	0.0087	0.0087	0.0087	0.0087	0.0105	0.0076	0.0087	0.0082
Nitrous Acid—								
Parts per 100,000	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Grains per gallon	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Nitric Acid—								
Parts per 100,000	0.13	0.13	0.13	0.12	0.13	0.13	0.10	0.13
Grains per gallon	0.0758	0.0758	0.0758	0.0758	0.0758	0.0758	0.058	0.0758
Oxygen required to oxidize Organic Matters—[Permanganate]—								
Parts per 100,000	0.47	0.477	0.41	0.445	0.445	0.477	0.47	0.477
Grains per gallon	0.274	0.278	0.24	0.259	0.259	0.278	0.274	0.278
Chlorine—								
Parts per 100,000	0.425	0.450	0.475	0.450	0.500	0.475	0.475	0.500
Grains per gallon	0.247	0.262	0.277	0.262	0.291	0.277	0.277	0.291
Hardness—								
Parts per 100,000	4.71	4.57	6.43	5.86	5.7	6.0	5.7	5.86
Grains per gallon	2.74	2.66	3.75	3.41	3.32	3.5	3.32	3.40
Total Solids—								
Parts per 100,000	9.4	8.8	10.8	11.90	10.7	10.7	11.7	10.60
Grains per gallon	5.48	5.13	6.3	6.93	6.23	6.23	6.82	6.18
Mineral Matter—								
Parts per 100,000	6.1	6.2	7.5	9.20	6.9	7.5	8.5	9.40
Grains per gallon	3.55	3.6	4.37	5.36	4.02	4.37	4.95	5.48
Organic and Volatile Matter—								
Parts per 100,000	3.3	2.6	3.3	2.70	3.8	3.2	3.2	1.20
Grains per gallon	1.92	1.51	1.92	1.57	2.2	1.9	1.9	0.70
Dissolved Gases by Volume—								
Oxygen, cub. centimeters per liter	4.36	3.7	3.34	4.33	....	4.62	3.93	4.50
Carbon dioxide " " "	1.97	0.74	1.21	2.06	....	1.49	1.12	0.37
Nitrogen " " "	12.02	13.44	17.05	11.15	....	11.87	11.40	14.08
Tot. Gases, cub. centim. per liter	18.35	17.88	21.60	17.54	......	17.98	16.45	18.95

TABLE IV.—MOHAWK RIVER, DRIVEN WELL, AND HUDSON RIVER, FILTERED AND UNFILTERED.

Laboratory Number	884.	886.	888.	889	883.	887.	885.
Special Number	XXI.	XXII.	XXIII.	XXIV.	XXV.	XXVI.	XXVII.
Location	Mohawk Rvr., above Falls.	Mohawk Rvr., below Falls.	Hudson Rvr., Waterford.	Albany Intake.	Albany City Hall (unfiltrd.)	Albany City Hall (filtered).	Greenbush Flats, Driven Well, No. 1.
Date	Oct. 30th.	Oct. 30th.	Oct. 31st.	Oct. 31st.	Oct. 30th.	Oct. 30th.	Oct. 31st.
Color	Very turbid.	4.5	5. Very turbid	Very turbid.	2.0	0.	0.
Taste	Pleasant.	Slightly peaty	Slightly unpl.	Slightly unpl.	Pleasant.	Slightly unpl.	Pleasant.
Smell	Marshy.	None.	Vegetable.	Vegetable.	Vegetable.	None.	Slightly unpl.
Free Ammonia—							
Parts per 100,000	0.005	0.005	0.0065	0.0115	0.005	0.0055	0.0055
Grains per gallon	0.0029	0.0029	0.0038	0.0067	0.0029	0.0032	0.0032
Albuminoid Ammonia—							
Parts per 100,000	0.018	0.016	0.02	0.021	0.0155	0 011	0.028
Grains per gallon	0.0105	0.0093	0.0117	0.0122	0.009	0 0064	0.0163
Nitrous Acid—							
Parts per 100,000	Trace.	Trace.	None.	None.	None.	0.0032	Trace.
Grains per gallon	Trace.	Trace.	None.	None.	None.	0.0019	Trace.
Nitric Acid—							
Parts per 100,000	0.50	0.45	0.05	0.10	0.05	0.05	0.12
Grains per gallon	0.29	0.26	0.029	0.058	0.029	0.029	0.07
Oxygen Required to Oxidize Organic Matters [Permanganate]—							
Parts per 100,000	0.58	0.56	0.72	0.70	0.63	0.12	0.08
Grains per gallon	0.338	0.326	0.42	0.408	0.367	0.07	0.047
Chlorine—							
Parts per 100,000	0.50	0.50	0.375	0.45	0.50	0 60	6.95
Grains per gallon	0.291	0.291	0.218	0.262	0.291	0.35	4.05
Hardness—							
Parts per 100,000	8.4	7.6	4.4	6.3	6.4	6.9	2.7
Grains per gallon	4.9	4.43	2.57	3.67	3.73	4.02	1.57
Total Solids—							
Parts per 100,000	16.8	12.7	7.9	13.1	1.8	9.5	32.6
Grains per gallon	9.79	7.4	4.6	7.59	6.88	5.54	19 01
Mineral Matter—							
Parts per 100,000	11.5	9.2	4.6	10.1	7.9	6.5	30.3
Grains per gallon	6.7	5.36	2.68	5.84	4.6	3.79	17.6
Organic and Volatile Matter—							
Parts per 100,000	5.3	3.5	3.3	3.0	3.9	3.0	2.3
Grains per gallon	3.09	2.04	1.92	1.75	2.28	1.75	1.41
Dissolved Gases by Volume—							
Oxygen dissolved in 1 liter	3.07	3.95	3.55	4.24	3.30	2.86	2.26
Carbonic Acid " "	2.82	1.72	1.48	1.60	2.90	2 97	3.54
Nitrogen " "	18.18	13.56	15.81	14.13	17.10	18.60	22.16
Total Gases dissolved in 1 liter	24.07	19.25	20.84	19.97	23.30	24.43	27.96

TABLE V.—ANALYSES OF MINERAL CONSTITUENTS.

Laboratory Number	826		827		828		830		872		½ of 884 & ½ of 886	
Special Number	I.		II.		III.		V.		XI.		½ of XXI. & ½ of XXII.	
Location	Snyder's Lake, Middle.		Sand Lake, Middle		Poestenkill Riv. at E. Poestenkill		Pumping Well of Alb'ny Pumping Station.		Dr. Helmes' Farm.		Mohawk River, above and below Falls.	
Date	September 4th.		September 4th.		September 4th.		September 5th.					
	Parts pr 100,000	Grs. pr gal.	Parts pr 100,000	Grs. pr gal.	Parts pr 100,000	Grs. per gal.	Parts pr 100,000	Grs. per gal.	Parts pr 100,000	Grs. per gal.	Parts pr 100,000	Grs. per gal.
Silicic Anhydride	0.220	0.128	0.090	0.052	0.550	0.321	0.440	0.257	0.880	0.513	1.580	0.921
Phosphoric anhydride	......	......	0.007	0.004	0.010	0.006	0.040	0.023			......	......
Sulphuric Anhydride	0.440	0.256	0.380	0.222	0.160	0.093	0.650	0.379	0.590	0.344	1.370	0.799
Carbon Dioxide	1.570	0.916	0.440	0.257	0.090	0.052	2.648	1.545	5.310	3.097	2.030	1.184
Chlorine	0.300	0.175	0.210	0.122	0.340	0.198	0.340	0.198	2.090	1.219	0.500	0.292
Potassium Monoxide	0.040	0.023	0.070	0.041	......	......	0.080	0.047	Trace.	Trace.	......	......
Sodium Monoxide	0.800	0.467	0.280	0.163	0.220	0.128	0.430	0.251	6.340	3.697	0.970	0.566
Magnesium Oxide	0.180	0.105	0.020	0.011	0.003	0.002	0.320	0.187	1.120	0.653	0.330	0.192
Calcium Oxide	1.440	0.840	0.620	0.362	0.300	0.175	3.060	1.784	1.530	0.892	2.610	1.522
Aluminium Oxide	......	......	0.006	0.003	0.090	0.052	0.030	0.017	} 0.490	0.286	......	......
Ferric Oxide	0.100	0.058	0.064	0.037	......	......	0.310	0.181			0.730	0.426
	5.090	2.968	2.187	1.274	1.763	1.027	8.348	4.869	18.350	10.701	10.120	5.902
Deduct Oxygen for Combined Chlorine	0.210	0.122	0.080	0.047	0.050	0.029	0.120	0.070	0.470	0.273	0.110	0.064
Mineral Matters	4.880	2.846	2.107	1.227	1.713	0.998	8.228	4.799	17.880	10.428	10.010	5.838
Organic Matters	1.890	1.102	1.360	0.793	1.229	0.717	4.178	2.438	4.020	2.344	3.200	1.866
Total Solids in Solution	6.770	3.948	3.467	2.020	2.942	1.715	12.406	7.237	21.900	12.772	13.210	7.704
Silicic Anhydride	0.220	0.128	0.080	0.048	0.550	0.321	0.440	0.257	0.880	0.513	1.580	0.921
Potassium Sulphate	0.080	0.047	0.120	0.070	......	......	0.150	0.087	......	......	......	......
" Chloride	......	......	......	......	......	......	......	......	Trace.	Trace.	......	......
Sodium Carbonate	0.470	0.274	......	......	......	......	......	......	6.930	4.041	......	......
" Sulphate	0.600	0.350	0.230	0.134	......	......	0.310	0.181	1.060	0.617	1.200	0.700
" Chloride	0.490	0.286	0.350	0.204	0.410	0.239	0.560	0.326	3.450	2.012	0.820	0.478
Magnesium Carbonate	0.400	0.233	0.050	0.029	0.010	0.006	0.670	0.391	2.350	1.371	0.700	0.408
Calcium Carbonate	2.570	1.499	0.860	0.503	0.200	0.117	4.970	2.898	2.720	1.587	3.780	2.204
" Sulphate	......	......	0.340	0.198	0.280	0.163	0.680	0.397	......	......	1.210	0.708
" Chloride	......	......	......	......	0.150	0.087	......	......	......	......	......	......
Aluminium Phosphate	......	......	0.013	0.007	0.020	0.012	0.070	0.040	......	......	......	......
" Oxide	......	......	......	......	0.080	0.047	......	......	} 0.490	0.286	0.730	0.426
Ferric Oxide	0.100	0.058	0.064	0.037	......	......	0.310	0.181				
Mineral Matters in Solution	4.930	2.875	2.107	1.230	1.700	0.992	8.160	4.758	17.880	10.427	10.020	5.853
Organic Matters	1.890	1.102	1.360	0.793	1.230	0.717	4.178	2.438	4.020	2.344	3.200	1.866
Total Solids	6.820	3.977	3.467	2.023	2.930	1.709	12.338	7.196	21.900	12.771	13.220	7.719
Lead, Copper, and other Injurious Metals	None.		None.		None.		None.		None.		None.	

I insert the accompanying five tables, partly to render intelligible what follows, and partly because the results are not in accordance either with the preconceived ideas of the inhabitants of Albany, or with the anticipations of the members of the Special Commission, the engineers in charge, or my own.

For, in the first place, the samples taken from the mountain lakes and streams do not compare favorably with the sample taken from the Hudson at the same date. It will be found by reference to Table I., that the albuminoid ammonia in the samples from Snyder's Lake, Sand Lake, Poestenkill River, and Dykeing Pond is greater than at the Albany pumping station, and the free ammonia is likewise greater, except in the case of Snyder's Lake. The required oxygen for the Poestenkill is enormous, as also the nitric acid of the Dykeing Pond. I conclude from the latter fact that the water in this pond contained, prior to the time of the analysis, an even larger percentage of decomposable nitrogenous matter than is indicated by its albuminoid ammonia. In other words, a large amount had been destroyed by natural processes of oxidation, and had been converted into nitric acid. The evidence of this oxidizing action is still further shown in the percentage of carbon dioxide in the Dykeing Pond sample, amounting to the very unusual volume of 6.56 c.c. per liter. The quantitative measurement of the color, which is of a yellow to reddish-yellow tint, in the two samples just alluded to, gives 1.25 and 1.75 respectively. This color is a stain due to coloring matters of peaty origin in solution, and is accompanied by a rise in the amounts of required oxygen to 1.90 and 0.60. The quantitative measurement of color in this way becomes an index of the oxidizable organic matter. The same fact is illustrated by a comparison of the waters of the Hudson taken Sept. 5th and 16th, but, in addition, these two samples expose the fallacy of an opinion popularly prevalent concerning river waters. For the first was taken immediately on resumption of pumping after an interval of four days, during which interval the river had been rendered so yellow and turbid by recent rains, that the engineers had regarded it unfit to drink. As a matter of fact, its ammonia yielding constituents had been diminished. And the same water on keeping in the laboratory [storage and sedimentation], became of a high order of purity, most of the micro-organisms either dying, or being precipitated as resting spores along with the sediment. In the reports on the proposed new water supplies of Wilmington, Del., and Philadelphia, numerous illustrations are given of the action of suspended aluminous matter [mud], in removing the ammonia-yielding organic constituents of the water.

In this connection, the beneficial effects of recent rains in raising the percentage of the dissolved oxygen should likewise be noted. This dissolved oxygen after a time is used up in oxidizing dissolved organic impurities, the percentage of carbon dioxide at the same time rising. Furthermore, as will be seen by reference to the Dykeing Pond sample, in proportion as the organic nitrogen becomes converted into nitric acid, the oxygen essential to this process is used up, and the percentage of dissolved oxygen exhibits a correspondingly low figure.

The analyses summarized in Table III. are of interest, both as relates to the potability of sewage-polluted water, like the Hudson River at Troy and Albany, and also in relation to the question of the self-purification of a flowing stream.

It will be seen that the absolute amount of free ammonia is very small, being only 0.003 per 100,000, in four of the samples, and even less in the remaining four. The albuminoid ammonia is also moderate in amount, being less in the Waterford sample than it is in that taken at the Albany pumping station, Sept. 5th, which sample, as we have just seen, contains a smaller quantity than is present in any of the lakes of Rensselaer County. The percentage of albuminoid ammonia in the Waterford sample is the same as that present at the Troy pumping station, and also at one and at two miles below Troy. Three miles below it rises sharply in amount, an increase due unquestionably to considerable local contamination near the point where the sample was drawn from the river. But it falls again at the point 1,400 feet above the Albany intake, the sample collected on the ebb tide having less putrescible organic matters than were present in any of the eight samples taken from the Hudson at this time. At the intake itself the albuminoid ammonia is 0.014 parts per 100,000, as against 0.015 parts at Waterford, Troy, and at one and two miles below.

One mile below Troy, the amount of oxygen requisite to effect the oxidation of the organic matters is less than at Waterford, which is situated on the Hudson some distance above Troy, and entirely above and beyond the influence of the Troy sewage. And although at certain intermediate points it again increases by organic matters locally added at these points, it does not exceed, even at the Albany intake, its amount at the Troy intake. The chlorine increases in the seven miles from Waterford to the Albany intake. This increment is a rational one, since it applies to a mineral constituent of sewage, and not to a constituent capable, like the matters above alluded to, of progressive oxidation.

All the Hudson River samples exhibit traces of nitrous acid, a very important fact, showing the reality of the existence of recent sewage contamination at every point examined. The nitric acid is the same, namely, 0.13 parts of 100,000 in all the samples taken on the ebb tide. It is notably less than the one sample taken on the flood, a result probably due to the reduction of the nitrates in contact with the fresh sewage sweeping upward past the Albany docks.

The minimum amount of dissolved oxygen is at one mile below Troy, at which point the oxygen has been exhausted by contact with the fresh sewage, and where it has had no opportunity to increase, as it does in the further run down the river.

Passing now to Table II., it will be seen that the free ammonia is much greater in the driven well than in the surface water, whilst the albuminoid ammonia is less. I attribute this result to the oxidation occurring in the pores of the ground, through which the meteoric waters filter before reaching the gravel stratum out of which they rise. In consequence of this oxidizing action, the nitrogenous matters are decomposed, and pass out of the putrescible condition in which they yield albuminoid ammonia, into the more stable form in which they yield free ammonia.

The chlorine in the wells is immensely greater than in the surface waters, but this chlorine is not indicative of infiltration of sewage, but is connected with a simultaneous large increase of all the mineral constituents due to the solution of mineral substances by the waters in the course of their filtration through the ground.

When we come to the dissolved gases, we find corresponding differences in the percentages of oxygen, due to the oxidizing action alluded to above, and inseparably connected with any process of beneficial filtration, whether it be effected by natural or by artificial means. The gases held in solution in superficial ground waters are principally derived from the atmospheric air with which these waters are in contact, both superficially and in the interstices of the soil. Such being the case, we can readily understand why the air dissolved in the driven well samples is impoverished in respect of its oxygen, and why it contains a relatively larger amount of nitrogen. The carbon dioxide generated by oxidation processes, rarely remains permanently in solution, being used up by plant organisms for their food, or seized upon by lime and other bases to form mineral carbonates.

Table No. IV. presents in the first place a comparison of a specimen taken from the Mohawk River above the Falls, with one taken below the Falls, on the same day. They are both, like those taken from the Hudson River at Waterford and at the Albany Intake, very turbid and deeply yellow colored. That taken above the Falls, like the one from the intake, is so muddy and opaque that its color could not be qualitively estimated by means of the color-meter. In taste, both the Mohawk samples were better than those from the Hudson, that taken from above the Falls being the only one entirely agreeable in flavor.

In respect of free and albuminoid ammonia and of oxygen required to oxidize organic matters, they were superior in quality to the Hudson River samples: in respect of chlorine, hardness and total organic and volatile matters, they were inferior. I am at an entire loss to know, not having personally visited the spot and collected these samples, why the sample taken below the Falls was on the whole of better quality than that taken above. I can only infer, from the increased percentage of the dissolved oxygen gas and the simultaneous diminution of the albuminoid ammonia and of the oxygen required in the laboratory to effect the oxidation of the organic substances in the two waters, that in their passage over the Falls a notable aeration and improvement had been brought about. Simultaneously with this change, a process of subsidence and precipitation in the river below the Falls appears to have taken place, by which means the mineral matters and the hardness underwent a very considerable diminution. But, notwithstanding this improvement, I do not think the difference in quality is sufficiently in favor of the Mohawk to warrant a recommendation to transfer the source of supply to this river. This view is much strengthened by the fact that the Mohawk is a harder water than the Hudson, and the difference in this respect would result in a considerable pecuniary loss to those engaged in manufacturing operations, and to the population at large in relation to its laundry use.

Proceeding now to the samples taken directly from the Hudson, October 21st, we note that in their physical properties the samples taken at Waterford and at Albany exhibit the same characteristics, being both dark colored, very turbid, and of slightly unpleasant taste. They show in a most striking manner an increase in the permanent mineral constituents, along with little corresponding change (and in regard to two classes of results even a diminution) in their organic constituents. For, at Waterford, the chlorine is 0.375 parts per 100,000, while at Albany it has increased to 0.45 parts ; at Waterford the hardness is 4.4, at Albany 6.3 ; at Waterford the total solids and mineral matters are 7.9 and 4.6, respectively, as against 13.1 and 10.1 parts at the Intake of the Albany station. Referring now to the organic constituents, we see that the free ammonia at Albany is nearly double what it is at Waterford, whilst the measure of the nitrogenous impurities themselves has increased by only 0.001 part. The oxygen required to effect the oxidation of the organic matters is 0.02 parts less at Albany than at Waterford, and the total organic and volatile matters are 0.3 part less. Along with this progressive oxidation, there is an increase in the percentage of carbon dioxide originating from it.

A comparison of the water running from the faucet of the City Hall, before and after filtration, shows that an improvement has thereby been effected. The improvement is most striking in the oxygen required to oxidize the organic matters of which only 0.12 parts were required for the filtered as against 0.63 for the unfiltered. The total organic matters for the filtered is 3 parts as against 3.9 parts for the unfiltered. But, during the process of filtration, the oxygen dissolved in the water has been used up, and in its place we find an increased quantity of carbon dioxide. Not only is the filtered water very poor in oxygen, but it contains a measurable amount of nitrous acid, which is present in waters only when the average matters which they contain have undergone incomplete oxidation.

Biological Analysis.

No biological analyses were made of the Rensselaer County waters, my arrangements for this part of the work not having been completed. The ten duplicate specimens taken from the Hudson River, between Waterford and Albany, September 29th, showed the following results: At the end of 48 hours, the culture tubes pertaining to all the specimens were unchanged. At the end of five days the gelatine in the culture tube belonging to the specimen collected opposite to Roy's factory was entirely liquefied; that in all the other culture tubes almost entirely liquefied. The number of microbes was greatest in the culture tube belonging to the specimen taken three miles below Troy, and least in the culture tubes of those specimens from the Albany and Troy intakes. Judging from the results of the biological analysis, the water collected at the Albany intake certainly did not contain more microbes than that from the Troy intake. These two waters were the best. The samples from Waterford were inferior to the two preceding, and of the three Waterford samples themselves, that from the east shore was the best, that from the middle the worst. The latter indeed was no better than the sample taken 1,400 feet above the Albany intake. In the following table I have arranged this set of Hudson River samples in two series, in one of which they are ordered in accordance with their excellence as decided upon chemical, in the other upon biological grounds:

SERIES NO. II., HUDSON RIVER SAMPLES, SEPT. 29TH.

A.—Chemical Order.	*B.—Biological Order.*
I. 1,400 ft. above Albany Pumping Station.	I. Albany Pumping Station, Troy Pumping Station.
II. Albany Pumping Station.	II. 1,400 feet above p. s., flood.
III. Waterford.	III. Two miles below Troy.
IV. Troy Pumping Station.	IV. One mile below Troy.
V. One mile below Troy.	V. Waterford.
VI. Two miles below Troy.	VI. 1,400 ft. above p. s., ebb.
VII. 1,400 ft. above Albany Pumping Station, flood.	VII. Three miles below Troy.
VIII. Three miles below Troy.	

In the biological analysis of the driven well samples, taken October 19th, and the Albany pumping station of the same date, the culture tubes of the former did not show any micro-organisms until the ninth day, when they first made their appearance, and finally brought about a liquefaction of the gelatine at various dates from the tenth to the eighteenth day. The Troy

Flat sample of this date presented similar characteristics, and underwent liquefaction in the same interval of time as the samples from the Three Hills and Dr. Helme's farm. The Albany sample exhibited organisms on the first day, began to liquefy at the expiration of sixty hours, and completely broke down on the third day with the appearance of very numerous microbes.

In the biological examination of the fourth series, the water taken from the Greenbush Flats driven well, No. 1, developed most microbes; that from the Mohawk River, below the Falls, the next largest number; that from the Albany intake followed third; that of the Albany City water, after filtering, fourth, before filtering, fifth; above the Mohawk Falls, sixth, and that from Waterford, last. Or, to rate them according to their purity, from a biological standpoint (though none of them were by any means free from microbes), their order would be as follows, the corresponding order on chemical grounds being added for comparison :

Series IV., from Mohawk and Hudson, Oct. 30th.

A.—Chemical Order.	*B.—Biolog'cal Order.*
I. Albany City Hall (filtered).	I. Waterford.
II. " " (unfiltered).	II. Mohawk River, above Falls.
III. Mohawk River, below Falls.	III. Albany water, before filtering.
IV. " " above "	IV. " " after "
V. Hudson River at Waterford.	V. Albany intake.
VI. " " Albany.	VI. Mohawk River, below Falls.
VII. Greenbush Flats, driven well.	VII. Greenbush Flats, driven well.

Experimental Investigation.

The analysis of the samples, before purified by oxidation processes and filtration in the manner previously indicated, will be found in the accompanying tables. My time allowed analysis of the purified samples only as far as the determination of the three most important factors free ammonia, albuminoid ammonia, and required oxygen. The results obtained were as follows :

Purifaction by Oxidation and Filtration.

Snyder's Lake.

	Before Purification.	After Purification.
Free ammonia.............	0.002 pts. per 100,000	0.012 pt. per 100,000
Albuminoid ammonia......	0.037 " "	0.012 " "

Sand Lake.

	Before Purification.	After Purification.
Free ammonia	0.009 pts. per 100,000	0.01 pt. per 100,000
Albuminoid ammonia	0.029 " "	0.01 " "

Dykeing Pond.

	Before Purification.	After Purification.
Free ammonia	0.014 pts. per 100,000	0.01 pt. per 100,000
Albuminoid ammonia	0.026 " "	0.012 pts. "
Required oxygen	0.60 " "	0.214 " "

Poestenkill River.

	Before Purification.	After Purification.
Free ammonia	0.011 pts. per 100,000	0.011 pts. per 100,000
Albuminoid ammonia	0.032 " "	0.0115 " "
Required oxygen	1.90 " "	0.88 " "

Albany Pumping Station, Sept. 5th.

	Before Purification.	After Purification.
Free ammonia	0.004 pts. per 100,000	0.01 pt. per 100,000
Albuminoid ammonia	0.019 " "	0.008 pts. "
Required oxygen	1.20 " "	0.293 " "

The meaning of these figures is, that the putrescible matter, taking the albuminoid ammonia as its index, had been mostly removed, in one instance only 30 per cent. remaining of the 100 present in the original unpurified water. And furthermore, that the total organic matter, taking the oxygen required to oxydize it as an index had been still more perfectly removed, the purified Albany intake sample containing only 24 per cent. of the oxidizable organic substances originally present.

The free ammonia, derived as it is from nitrogenous bodies by processes of oxidation, was in most instances increased.

These surprising and very gratifying results were obtained by simple means in the laboratory, and there is no practical obstacle that I know of, to their economical application on the scale necessitated by the supply of a large city like Albany.

General Comparison of Results.

On a general survey of these results, there would appear to be no good reason why the waters from any one particular locality should be exalted above all the others, and in this manner the source of supply, so far as the vital question of purity is concerned, should be settled. Only by the critical weighing of many considerations and by the exclusion of such sources as have previously been shown to be inferior for reasons already given in the text, can the problem be so narrowed down that its solution becomes feasible.

We should, therefore, begin by excluding the samples from Rensselaer County ; the Mohawk River waters ; all the samples from the Hudson River proper, except those from Waterford, Troy pumping station, the Albany intake, and 1,400 feet above the intake. Then, of those which remain, we shall begin by comparing those taken from the Hudson River among themselves. In the first place, they are all alike in containing some unoxidized sewage. It is present at Waterford, at Troy pumping station, and, although undergoing a certain amount of oxidation on its way down the river, it is neither at the Albany pumping station, nor 1,400 feet above, so far eliminated that the water taken directly from the river at the Albany intake is of sufficient purity for potable use.

We shall, therefore, exclude the Hudson River as taken *directly* at any point, beginning at Waterford, down to Albany, from the recommendable sources of future supply.

The case, however, is different with regard to the Hudson waters subjected to processes of purification and filtration ; for, while the particular sample of the Albany water filtered at the City Hall did not afford satisfactory results, yet it is possible by simple and practical means to purify them thoroughly, so that they shall not contain organic matters dangerous to health, nor organized particles, in the form of germs, capable of originating disease.

With regard to the driven wells, the testimony concerning those on the Troy Flats is conflicting, the earlier sample being satisfactory from a chemical and biological standpoint, whilst the latter sample was anomalous in both. Although analyses are needed in the future, to decide the cause of these anomalies, yet as far as an opinion can be formed from the nature of the evidence now in my possession, I believe them to be accidental, and that the water taken from the driven wells on the Flats, would prove to be both satisfactory for manufacturing use, and safe and wholesome for domestic purposes.

The water from the driven wells at Dr. Helmes' farm contains 10.43 grains per gal., as against 4.76 grains in the Hudson River water at Albany (see analysis of September 5th), but an examination of Table V., shows that these saline matters are not of a character to injure the water for manufacturing purposes, nor do they give other than an agreeable taste.

I would, therefore, include the water from this and the neighboring Three Hills farm, among those capable of supplying Albany with satisfactory and wholesome drinking water.

CONCLUSIONS.

Two classes of considerations must be kept in view in drawing these conclusions; the one relating to the use of a city water supply for drinking and domestic purposes, and the other, which we can by no means afford to lose sight of, in view of the enormous pecuniary interests involved, its use for laundry and manufacturing purposes.

As to the first, no water is fit for drinking and domestic purposes, unless it is entirely odorless, colorless, perfectly pellucid and transparent; free from turbidity and suspended particles; of no taste, or, if any, a pleasant one, and demonstrably free from all non-organized or organized matters (in the shape of germs) capable of originating disease.

Now, it is no proof that these requirements are either unnecessary or exaggerated, that most of the cities in this country and the old world, are supplied by water which does not conform to them. Public opinion on these matters has developed aggressive strength only during the last few years, and indeed could not be formed on impregnable grounds except with the aid of the scientific discoveries of the past ten years. Now, that it has been demonstrated that the chief agency in the transmission of cholera, typhoid fever, and zymotic diseases in general, is by means of organized germs diffused in drinking water, the popular demand for sources of water supply demonstrably free from organic impurities is imperative, and legislatures and municipal authorities must obey it.

Whenever appealed to, the courts in this country have affirmed by decisions in conformity with very emphatic charges from the bench, that corporations and individuals could not abuse the waters of a flowing stream used for water supply, by emptying sewage into it. At the present time, the citizens of Albany are drinking a residual portion of the sewage of Troy, and a part of their own sewage. The citizens of Troy are consuming as a beverage some unoxidized sewage from points above them on the Hudson. It remains for legislative enactment and a humane and wise public opinion to compel these and all other communities to reclaim their sewage, before emptying the effluent waters therefrom into a flowing stream. Simple, economical, and completely effectual methods for so doing, are now known and practiced by sanitary engineers.

But even granting that this is done, the consumer should have the water delivered to him in the limpid and demonstrably pure condition above spoken of. And under no conditions can he be guaranteed in the possession of such a water supply, unless it be thoroughly purified and filtered immediately before use. This can be done either artificially or naturally. The water taken from the driven wells at the Three Hills and Troy Flats farms, and that taken from the Hudson River at Albany and properly purified, are equally limpid, colorless, odorless, and free from micro-organisms of every description.

From a sanitary, a chemical, an experimental and a biological standpoint, I can affirm that either of these two modes of supply will afford the people of Albany equally pure and wholesome drinking water.

With regard to their use for manufacturing purposes, a somewhat similar statement can be made.

The driven well waters contain a considerably larger amount of mineral substances in solution than the river waters. But the detailed analyses given in Table V., show that this excess is due to an increase in the amount of the soda salts, and not to an increase in the amount of lime and magnesia salts. Did they exhibit an increase of the latter constituents, they would not be, as in fact they are, soft waters, and would not be adapted for laundry use. At the same time there would be an advantage in lowering the percentage of saline constituents in the driven well water, varying as they do, from 10 to 20 grains per gallon, by using it in connection with the river water, whose mineral constituents are about 4.5 grains.

For the various reasons detailed in the body of this report, I would finally recommend :

That the City of Albany should avail itself of the advantages and guarantees of a twofold system of water supply.

I. Hudson River water, purified and filtered.

II. Driven well water.

In case the former is adopted, I would further recommend :

1st. That the water should be taken above Albany, at some point above the influence of the Albany sewage, and when time and distance had been afforded to allow the maximum possible self-purification of the Troy sewage.

2d. That the water should not be taken directly from the river, but through a curb or well, arranged to exclude the surface water and the grosser organic and mineral impurities.

3d. That the water should be brought from the intake located in this well to the present pumping station, and from thence lifted to the reservoir.

4th. That it should be purified and filtered immediately before delivery into the reservoir.

In case the driven well system is adopted, I would recommend :

1st. That as much water should be drawn from the wells in the Three Hills farm tract as they are capable of affording ; and, in case they prove inadequate or it should appear desirable to extend the system,

2d. That the system should be extended to the Troy Flats.

3d. That the deficiency of oxygen in the driven well waters should be made up by charging them with air under pressure in the course of their transmission through the mains from the wells to the reservoir.

APPENDIX.

The above experimental inquiries are, for the reasons previously given, of a merely introductory character, but it is important to present, so far as I am acquainted with it, the history of this part of the subject. In the months of January and February, 1883, the water of the Schuylkill River became so nauseous in taste and smell that it was not potable, and I was requested by the water department of that city to examine into the origin of the malady. It was not revealed by the chemical analyses of the samples, although these analyses were extended to the determination of gaseous, mineral and organic constituents ; but, by experimental treatment in the laboratory, I found that the oxygen present in solution, which was abnormally low in the original samples taken from the Schuylkill river could be readily raised to its normal amount, and that I could effect a corresponding diminution in the amount of organic constituents. It was proposed that the percentages of organic matters which could be eliminated, and more especially the nitrogenous organic matters, should be taken as indicating the indices or co-efficients of impurity; and, similarly, the amounts of oxygen which had to be added were proposed as a measure of the inferiority of the samples examined below a feasible condition of purity.

The practical benefit of these experimental inquiries is daily experienced in the case of the water supply of Hoboken, which amounts to 4,000,000 gallons, and which for the past year and a half has had its deficiency of oxygen supplied by the injection of air under pressure, and a similar method of treatment was recommended, and is being introduced at the several pumping stations of the Philadelphia Water Department.

It is possible to obtain, by simple methods of laboratory experiment, an effectual purification of the samples submitted to analysis. This being the case, we are compelled to abandon the different standards of relative purity which have been our only reliance hitherto, and to substitute for them absolute hygienic standards. The former class of standards have frequently been deduced from the comparison of city water supplies of fair repute. It is obvious that such standards must necessarily be of a degraded character. Or, in place of general standards so established, particular standards have been proposed. For instance, the pollution of the water supplies of Newark and Jersey City is measured by the differences between the results obtained by analyses of the Passaic water at the pumping stations, and the waters of the same river before it has encountered sewage contamination. The composition of the waters at Phœnixville has been proposed as a standard of purity of the sewage polluted Schuylkill at the pumping stations of Philadelphia.

But it can be readily demonstrated by laboratory experiment that these standards themselves are usually questionable, their character breaking down on applying the severe tests of biological analysis, and a large co-efficient of removable impurities being obtained on the application of the purification processes above alluded to. Such being the case, let us set aside these questionable standards of general and particular relative purity, and replace them by what might be termed absolute hygienic standards. That is to say, let us determine what and how much of the organic constituents of a water are eliminable by experimental laboratory purification. Let the fact of purification be established by biological analysis, when, if the purification is such as it should be, and such as is readily obtainable in the laboratory, biological analysis should show the destruction of micro-organisms by the purification method employed. Then let the character and analysis of the water thus purified be set up for an absolute hygienic standard in the case of the particular water experimented upon. How near, as a matter of chemical engineering, it may be desirable to realize in practice the supply to a large city of water conforming to the laboratory standard, it is foreign to the purpose of the present article to discuss. But it will be readily seen that this experimental method of water analysis supplies many facts of a practical nature, such as water commissioners demand information upon, whilst chemical analysis, *per se*, supplies such information only obscurely and inferentially. For the reasons above given, it appears to me that experimental water analysis affords the most promising field in connection with the subject of water supply.

In conclusion, I wish to state, in order to prevent my being misunderstood, that the presence of non-pathogenic microbes in sewage-polluted waters is of the greatest benefit, inasmuch as it is with the aid of the transformations effected in connection with their vital processes that oxygen is absorbed and the oxidation of decomposable organic matter principally accomplished. Furthermore, they antagonize and destroy the pathogenic bacteria, liable at all times to be associated with sewage. Their study, as a factor in water analysis, has been utilized for the reason that in proportion as sewage is oxidized with their aid, it disappears, and the diminution of sewage, the exhaustion of the dissolved oxygen, and the development of microbes, stand in definite relationship to one another. Furthermore, as the sewage is destroyed, or in waters containing no sewage, the microbes disappear for lack of favorable environment, and hence, even without determining what microbes in a water under examination are pathogenic and which are not (a problem beset at the present time with extreme difficulties), it may safely be set down that a water which is lacking both in sewage constituents and in microbes in general, and especially when it contains its normal percentage of oxygen, is hygienically pure.