Water Supply of Honolulu

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tionably one of the best supplies of any city in the United States.

The Nuuanu gravity supply is secured by impounding a limited supply of spring water and the storm waters of Nuuanu valley. These waters, except the water from the springs, are necessarily due to the condition of the drainage area, turbid and saturated with organic matter, and there has always been more or less complaint from consumers. In fact, for several weeks this past summer and now at the present time, my family had to abandon our home, situated in the Puunui district, at an elevation of 335 feet, as the water, in the first place, was absolutely unfit for human consumption, and, secondly, the supply was so limited that hardly enough could be obtained to water the domestic animals kept on the premises.

The present reservoirs in Nuuanu valley are three in number, with a total capacity of 39,000,000 gallons, and under ordinary conditions do not hold more than a ten-day supply, under conservation draught, so that it is impossible to derive potable water from the present source of supply in this valley. With the completion of Nuuanu Reservoir No. 4, the condition of the Nuuanu supply will be materially improved, inasmuch as the capacity of this reservoir is 639,000,000 gallons, and the water will have time before reaching the consumer to deposit much of the material held in suspension. Even so it will be necessary, if this water is to be used for domestic purposes, that a filtering plant be installed, as even under the most favorable conditions Nuuanu water, unfiltered, is not fit for human consumption.

In a further conversation with Superintendent Campbell, he stated that it was his idea to use artesian water for all purposes as far as possible. The reservoirs which he proposed as necessary, are, one to replace the present one at Kaimuki, of 1,500,000 gallons capacity; the pump capacity is 3,000,000, and while we are pumping people are consuming; the reservoir will act as a relief valve. A reservoir on Punchbowl at an elevation of 400 feet, another on Punchbowl at an elevation of 290 feet, and the present one on Punchbowl at an elevation of 160 feet. The system will then be divided into three levels—the low level, below 160 feet, which will be supplied from the three pumps, Kalihi, Beretania, and Kaimuki, being connected with a proper system of mains running through the town. The intermediate system will supply the area between 160 feet and 250 feet elevations, and will be taken care of by the 5,000,000 gallons from the electrically-driven pumps to be installed at Nuuanu Reservoir No. 4. The high-lift pump, at present at Honolulu Ironworks, will be placed in the Beretania pumping plant and will furnish 3,000,000 gallons per day, pumping to an elevation of 400 feet. The reservoir at 400 feet elevation will take care of that area between 250 and 400 feet. In carrying out the scheme, in dividing the town into three levels, three separate reservoirs are required. Below 160 feet level, which is the densely settled portion of the city, we have three reservoirs to take care of that portion. The Kaimuki and Punchbowl reservoirs are 160 feet, the Kalihi reservoir at 180 feet, and Diamond Head at 150 feet. This takes [illegible]re of everything below 160 feet level [illegible] Diamond Head to Kahauiki. There [illegible] additional pump at Makiki of [illegible]00 gallons capacity at an elevation of 160 feet. Mr. Campbell further states that we should have 7,800,000 gallons daily from Nuuanu Reservoir No. 4, but due to various losses he could count on only 5,000,000 gallons from the electrically-driven pump system.

Recapitulation.

Electrical-driven pump system	5,000,000
Beretania pump	3,000,000
Kalihi pump	5,000,000
Honolulu Ironworks pump (high-lift)	3,000,000
Makiki pump	1,000,000
Kaimuki	3,000,000
Spring water, Makiki (upper)	400,000
By purchase Pauoa water, additional supply (minimum)	1,000,000
	21,400,000

The advantage of this system would be that no water would be stored in any of the reservoirs in excess of two to five million gallons, the reservoirs would be covered and fenced and would be secure from intrusion and contamination. The present daily supply under normal conditions is approximately 13,000,000 gallons, and with the proposed artesian system a gain of about 8,000,000 gallons daily.

This contemplated supply would give us a daily average of 500 gallons per capita consumption. The maximum consumption per capita in any city of the United States is one-sixth to one-twelfth as much, and in large European cities it is as low as thirty gallons per capita. Of course, our conditions are materially different, as we use large quantities for irrigation purposes. In reply to a question put by me as to the relative cost between a filtration plant and the system above outlined, Mr. Campbell stated that to put in a modern, up-to-date filtration system, to filter 7,800,000 gallons of water, would cost for construction in the neighborhood of from $250,000 to $300,000. The entire artesian system, as above outlined, would cost approximately $200,000. Against the filtration plan, besides the original cost, might be added that it would be expensive to operate, as it would have to be in charge of thoroughly competent operators, assisted by chemists, etc., so that constant analyses of the raw and effluent waters could be made. Without such assistance, filtration would result in worse conditions than raw waters. Further, all the sands necessary for the filters would have to be imported from California, whereas, with the proposed artesian system, as outlined above, with new pumps, we would not require any additional assistance over that already employed at present, as they would be housed under the same roofs as at present occupied. Items of cost, as given by Expert Civil Engineer Rudolph Hering, was over $20 per million gallons, by the method of filtration, but probably the cost could be reduced considerably, as since that time methods have improved.

In reply to my question as to the disposition to be made of the water after its use for power purposes, Superintendent Campbell stated that there are three channels of Nuuanu valley water that converge into Nuuanu valley, viz. —Pauoa stream, main Nuuanu stream, and its branches. During ordinary weather these streams are full, and there is more or less drainage from cesspools and yards, etc., and they become a catchment basin. The idea is to utilize the waste waters and to keep a constant and steady stream of water flowing through the main channel. This would also stop mosquito breeding. It might also be used for irrigation of upper lands.

Continuous Filters and Their Construction.

Filtration of water consists in passing it through some substance which retains or removes some of its impurities. In its simplest form, filtration is a straining process and the results obtained depend on the fineness of the strainer, and this in turn is regulated by the character of the water and the uses to which it is to be put. Thus in the manufacture of paper an enormous volume of water is required, free from particles, which, if they should become imbedded in the paper, would injure its appearance or texture. Obviously for this purpose the removal of the smaller particles separately invisible to the unaided eye, and thus not affecting the appearance of the paper, and the removal of which would require the use of a finer filter at increased expense, would be a simple waste of money. When, however, a water is to be used for a domestic water supply and transparency is an object, the still finer particles which would not show themselves in paper, but which are still able, in bulk, to render a water turbid, should be as far as possible removed, thus necessitating a finer filter; and when there is reason to think that the water contains the germs of disease, the filter must be fine enough to remove with certainty those organisms so extraordinarily small that millions of them may exist in a glass of water without imparting a visible turbidity.

It is now over a half century since the first successful attempts were made to filter public water supplies, and there are now hundreds of cities with clear, healthy, filtered water. In fact it might be said that so universal has been the demand for pure water that no city with any pretensions or prospective growth has failed to avail itself of this or other means of furnishing a purer water supply. While the details of the filters used in different places present considerable variations, the general form is everywhere the same. The process is as follows: The raw water is taken into a settling basin, where the heaviest mud is allowed to settle. In the case of lake and pond waters the settling tank is dispensed with but it is essential for turbid river water, as otherwise the mud clogs the filter too rapidly. The partially clarified water then passes to the filter, which consists of a horizontal layer of rather fine sand supported by gravel and underdrained, the whole being enclosed in a suitable basin or tank. The water in passing through the sand leaves behind upon the sand grains the extremely small particles which were too fine to settle out in the settling basin, and is quite clear as it goes from the gravel to the drains and the pumps, which forward it to the reservoir or city.

The passages between the grains of sand through which the water must pass are extremely small. If the sand grains were spherical and 1-50 of an inch in diameter, the openings would only allow the passage of other spheres 1-320 of an inch in diameter, and with actual irregular sands much finer particles are held back. As a result the coarser matters in the water are retained on the surface of the sand, where they quickly form a layer of sediment, which itself becomes a filter much finer than the sand alone, and which is capable of holding back under suitable conditions even the bacteria of the passing water. The water which passes before this takes place may be less perfectly filtered, but even then, the filter may be so operated that nearly all of the bacteria will be deposited in the sand and not allowed to pass through into the effluent.

As the sediment layer increases in thickness with continued filtration, increased pressure is required to drive the desired volume of water through its pores, which are ever becoming smaller and reduced in number. When the required quantity of water will no longer pass with the maximum pressure allowed, it is necessary to remove, by scraping, the sediment layer, which should not be more than an inch deep. This layer contains most of the sediment and the remaining sand will act almost as new sand would do. The sand removed may be washed for use again, and eventually replaced when the sand becomes too thin by repeated scrapings. These operations require that the filter shall be temporarily out of use and as water must in general be supplied without intermission, a number of filters are built together so that any one of them can be shut out without interfering with the action of the others.

The relation of filters to the pumps varies with local conditions. With gravity supplies the filters are usually located below the storage reservoir, and, properly placed, involve only a few feet loss of head.

Superintendent Campbell endorses only the slow filtration system. It will take at least one acre in area to filter 3,000,000 gallons per day, so that to filter Nuuanu water, 7,800,000 gallons, we would have to use at least 2½ acres for filter beds. The plant must be duplicated so as to take care of all this water. A filtration plant would also require a clear water reservoir to hold from 3,000,000 to 5,000,000 gallons and this would have to be covered on account of the rapid growth of algae.

Bacteria in Water.

The ordinary water bacteria are of the harmless and beneficent kinds, which, depending upon dead organic matter for sustenance, bring about its conversion into simple chemical substances. How many species of these saprophytic organisms exist in water cannot be said, but about two hundred varieties have thus far been described. They may be present in small or enormously large numbers without being necessarily of hygienic significance, although their existence in large numbers indicates the presence of an abundance of organic matter, and yet they may thrive and multiply enormously in water containing almost no organic food materials. Indeed, multiplication occurs more rapidly in pure than polluted water, but diminution in numbers is also more rapid. In impure water they multiply slowly, but their growth is persistent, and, under ordinary natural conditions, sudden diminution in numbers does not occur. In ordinary water bacteria are found in much greater abundance in surface waters than in those derived from the soil. Indeed, many observers, including Koch and Fraenkel, have maintained that waters from the unpolluted supplies are particularly sterile. This, however, has been shown by Sedgwick and Prescott not to be the case.

The feces from a man contain on an average perhaps 1,000,000,000 bacteria per gram, most of them being the normal bacilli of the intestines, Bacillus coli communis. Assuming that a man discharges 200 grams or about seven ounces of feces daily, this would give 200,000,000,000 bacteria discharged daily per person. The number of bacteria actually found in American sewage is usually higher, often double this number per person, but there are other sources of bacteria in sewage, and in addition, growths or the reverse may take place in the sewers, according to circumstances. A considerable proportion of the water supplies of the cities of the United States are so polluted that in case cholera should gain a foothold upon our shores, we have no ground for hoping for the favorable experience of the English cities rather than the plague of Hamburg in 1892. The broad fact that cities with polluted water supplies as a rule have high typhoid fever death rates, and cities with good water supplies do not (except in the occasional cases of milk epidemics, or when they are overrun by cases contracted in neighboring cities with bad water, as in the case with some of Chicago's suburbs), is at once the best evidence of the damage from bad water and measure of its extent.

Through the courtesy of Mr. W. B. Stockman, Director of the U. S. Department of Agriculture, Weather Bureau, I am able to present the official report of the rainfall as regards the Nuuanu District.

Electric Light Station, from January 1900, to August 1908:

Average by months—5.69, 8.93, 8.44, 5.86, 4.73, 4.81, 4.90, 5.49, 5.48, 6.56, 7.51, 6.78. Annual, 75.94.

Greatest, by months—18.89, 22.56, 26.17, 13.22, 9.47, 10.47, 9.00, 9.09, 11.96, 13.91, 14.36, 15.42. Annual, 124.95.

Least, by months—0.63, 1.16, 0.87, 2.00, 1.03, 1.79, 0.92, 1.77, 1.43, 2.91, 1.17, 2.66. Annual, 56.08.

Luakaha, Lower:

Average, by months—9.22, 12.69, 14.06, 12.43, 10.16, 9.06, 9.82, 12.25, 10.99, 11.37, 12.62, 13.18. Annual, 138.06.

Greatest, by months—22.00, 27.96, 44.25, 25.06, 19.07, 15.72, 15.35, 24.83, 23.59, 21.21, 26.16, 26.50. Annual, 191.11.

Least, by months—2.45, 2.35, 2.55, 2.95, 1.78, 4.47, 5.63, 4.61, 2.24, 7.00, 3.26, 4.18. Annual, 85.12.

Purity of Water and Water Analysis.

As regards the purity of the water supply of Honolulu, I give the following analysis furnished by Food Commissioner Duncan in which a comparison of the artesian and Nuuanu waters is made; figures are expressed in parts per million. It will be seen that the Nuuanu supply is unusually contaminated with earthy and vegetable matter, is always turbid and occasionally of a very disagreeable odor:

Artesian.	Reservoir.
Turbidity—None.	Always turbid.
Sediment—None.	Always present.
Odor—None.	Vegetable and earthy and occasionally disagreeable.
Solids—214 to 247.	80 to 148
Total ammonia— 0.005 to 0.045	0.095 to 0.040
Free ammonia— 0.005 to 0.020	0.015 to 0.125
Albuminoid ammonia— 0.000 to 0.015	0.04 to 0.270
Chlorine—47 to 72.	17.5 to 21.0
Nitrogen as nitrates— 0.20 to 0.33	0.0 to 0.15
Nitrogen as nitrites— None	None to trace
Oxygen consumed— 0.35 to 0.90	1.35 to 4.80
Hardness—83.0.	30 to 36.0

Conclusion.

In weighing the relative advantages of the filtration and artesian systems, it would seem that the artesian system would be the most feasible when you take into consideration the original cost, expense of operating and the lesser danger of contamination in comparison to filtered water where the filters themselves may become foul through neglect. I believe the city of Honolulu has a great future before it, and no single factor will have greater weight with a person who wishes to become a resident than the assurance of an abundant supply of pure and wholesome water. I believe it is the duty of each and every medical man to take a firm stand in this important matter and while it may seem that we are unselfishly "cutting our own throats" professionally by advising measures to cut down disease, we are really advancing our interests by advising methods which if carried out will have a tendency to increase our population many fold and thus bring prosperity in many directions.