An Examination of the Sewage Discharged from Moon Island and Its Effect on the Waters of Boston Harbor.

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of the Sewage Discharged
from Moore Island and
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The subject undertaken is
one that has been but little
studied. It is said that
the sewage has been traced
to a certain extent down
the harbor by means of
floats. The above work
was considered to afford
a rare chance for a prac-
tical application of bacter-
iology. Scientifically it is
far more accurate than
the method of study by
floats. When the fact is
taken into account that sewage contains several million bacteria to the cubic centimeter, while fresh water contains but about ten, it is seen what a chance is given for the accurate tracing of the progress of the sewage, of its diffusion, and of the general effect on it of its environment. Consider a million floats put on each square foot of surface and still they would not give the same precision as, for instance, in telling how much salt water from below had mixed with the sewage above it.
The question is, to a certain extent, similar to that of the disposal of sewage in rivers, inasmuch as it is desired to know how much sewage might be allowed to enter the harbor before creating a nuisance. The work begun is on the discharge of sewage from Moon Island. The sewage comes from the Metropolitan District south of the Charles River. The amount flowing now is not, of course, equal to that which it will be some years hence, as the system was calculated for a maximum flow some time late in 1900. The sewage flows by
gravity to Harbor View Point, and in turn lifted by large pumping engines about thirty-three feet into what is practically a settling gallery. The sewage flows through this gallery and then passes by tunnel under Dorchester Bay, coming up on the other side at Squantum Head. From here it passes over to Moon Island in a sewer laid in a high embankment built by the city specially for this purpose. The sewage in here received in tanks or reservoirs, and is held until one hour after scheduled high tide when the gates are opened and
It flows directly into the harbor. The period of discharge takes, usually, a little less than an hour, depending upon the effect of the wind on the tide. The sediment in the tanks is flushed out by means of the sewage itself. The tanks at present are inadequate as they are full about a half hour ahead of time and the surplus must be allowed to run directly into the harbor. However plans are already drawn up for several new tanks.

The quality of the sewage discharged may next be considered.
Before reaching the pump, the sewage passes through some box screens which remove all large matter or sticks, rags, etc. It is interesting to note that fish and turtle have been stopped at these screens and taken out alive, though in what may be termed a "groggy" condition, presumably from the lack of oxygen in the sewage. Beyond the pump the sewage passes slowly through the long settling gallery. Here much of the sediment settles and is removed. Some fine material remains however as shown by the settling in the tanks, which
in flushed out on emptying. It is seen that the most objectionable matter is removed before discharge into the harbor.

It remains now to study the sewage after entering the salt water. For this it was necessary to do some preliminary work on the normal condition of the harbor water. The question that comes up is, 'what is the bacterial condition of pure sea water and what does it become in the harbor?' Professor H.L. Ru
cell of the University of Wis
coin did much work at Woonah Roll in 1892 on the
bacterial condition of the sea and the sea-floor. The number of bacteria in the sea was found to vary from three or four up to about one thousand and twenty. The species were worked out and those found greater proportion of bacteria were found to belong to about three varieties. In regard to vertical variation in number or kind there appeared to be an almost equal distribution. The bacteria were found to be in an active state of life, though at the same time by experiment many spores were shown to exist. The sea-floor at
Wood's Roll is far richer than the sea in bacteria, the average being 17,000 per cubic centimeter, which is the usual unit of measurement of number. They were found so far out from shore as samples were ever taken, the farthest being 100 miles from shore, on the edge of the littoral plane or extending along the sea-board. The forms found were indigenous each to its own sphere, though of course they were often found in each other's place due to settling or turbidity. Much variation in Boston Harbor Water would be expected from that of
sea water as it receives polluted river water, the Moon Island sewage discharged every 6 hours and the continuous sewage discharge from Deer Island. Several trips were made down the harbor to study this and its dependence on the tides. The first sample taken was from the Charles River at the draw of the Cambridge Street bridge, three hours after high-water. Ice was floating down the river. Actual count showed 22,000, but for ulterior reasons 25,000 would probably be nearer the true number. From the tug Cormorant of the city of Boston a series of
sample was taken extending from 8 miles east of Boston Light all the way up the harbor. On the way out about 4 miles east of the light a shark de-markation line was observed between the harbor and sea-water. This was a little after low water. The sample at sea, uncontaminated by harbor water, showed quite an agreement with the results of Russell. The number varied from 7 to 40 corresponding well with his work. It was intended to work out these species, but as it had already been done the idea was given up a little east of the light.
the number went up to 155 probably marking the change from the sea to the harbor water. Off Long Island the number had gone up to 1300, and in mid-channel off the New England R. R. docks, three hours after low water the number was 4,700. A sample taken here a half hour after low water gave 28,400. This corresponded with and showed the effect of the river water above it. Another trip on the coromant showed a variation from Ft. Warren out to sea of from 1000 down to 75, the tide being three to four hours out. It also gave some other
facts of interest. An impor-
tance was taken from the
St. Warren boat, as it was
along the course of the
sewage and only about
an hour before the first
discharge of sewage began.
This showed a variation
of 1500 at St. Warren up to
3500 at the northern point
of Long Island and of 2100 at
a half mile directly off the
sewer. At Spectacle Island
and the main channel the
head runs to 500 and 800.
This probably shows no se-
Wage contamination from the
previous pollution of
shores or bottom near
Moore Island, for this stage
of tide, because the water
from which these last samples came was undoubt-
edly that coming almost directly from the sea.
The high numbers were prob-
ably due to the low tide
water remaining in that
vicinity, and mixing or
rising with the incoming
water.

The next step was
the direct tracing of the
course and diffusion of
the sewage. The course
will be considered first.
The sewage on flowing out
spreads over a large surface
before going to sea, and
thus stands on the salt
water for some time. It
was obvious that at this time
of the year at least the sewage must tend to
remain on the surface. Three good reasons for its
drinking may be suggested. First, and strongest, it is
fresh water flowing out on
lower salt-water.
Next it is heavier than
salt water, at least at this
season. In the river the
temperature was 10.5 C, while
at the shore near the out-
flowing sewage the harbor
water was 14.5. The temper-
amount falls the nearer the
approach to fresh sea
water, for at Ft. Warren it
was 10.5 C. At new bedden
point of Boston Light and about
a month earlier it was
found to be only 5.5 C. To see if there was any difference in temperature between the water polluted and unpolluted, it was tried at a well defined edge about 1/4 mile from the outlet. Three feet inside the line it was 14.5 C, while three feet the other side it was only 14.0 C, which shows there was but a slight variation.

The last reason the sewage remains on the surface and does not mix immediately is that it contains much grease and soap, producing a smooth surface even under strong winds. Thus there is abundant reason for the sewage to
remain on the surface and
did war so well confirmed
by observation that it was
considered hardly necessary
to test it bacteriologically.
It may be seen drifting
along on the surface, the
fine flocculent matter bet-
traying its presence, while
the extent over the surf-
face is shown by the smooth-
ness and by the milky color
and reflection of the water.
By simply stirring with
the our small whirl-pools
may be formed by which
the purer water below
may be brought to the
surface in streaks, contrast-
ing strongly with the dir-
ty water. At the edges the
distinction is very sharp, the salt water appearing to form a sort of precipitate. The sun brings this effect out even in more striking contrast, as it passes through the sun warmer and in diffused by the flocculent matter. A curious result from this surface flow was noted some time ago. A diver said, that while calking the water pipe land from moon to Long Island he could always tell when the sewage was discharged because it spread over him in a thin sheet and shut out the light, thus compelling him to stop work. It may have been he was too
willing to stop, but nevertheless it helps to prove the conclusions drawn above.

The sewage stands spread over the surface much like in a reservoir. It usually reaches from Mean to Uptakele Island, from there to the southern end of Long Island, and from the south side of Shore Island in Quiney Bay down by a curving line to Quarantine Rocks. This line is about a half mile to a mile from the end of Long Island. There is no chance of its ever reaching the shore of Prison, as was feared once before, for only a severe
last wind could drive it that way and it is almost beyond reason to expect that it could be carried over 2 miles, which is the distance, against the tide and over shallow flats.

The only outlet taken by this sort of reservoir are those to the right and left of Quarantine Rocks and between Rainford and Long Island. It has never been known, by observation, to pass out to the main ship channel by the passage between Spectacle Island and between Spectacle and Long and Thompson Islands. In neither case observation is perfectly trustworthy in the open.
ings are so near Moira In-
land that the sewage in
little diluted and if flow
would easily be traced by eye.
From a consideration of the
chart it is seen that the
sewage would not use these
passages for they are so
shallow that there is no
set of the tide through them.
Except with the strongest
north or south winds the
sewage would always use the
openings mentioned above.
The channel between Rainsford
and Long Island appears to
be the natural course as it
is so much deeper than
the others, but among the
rocks, and especially between
them and Rainsford Island,
there is a strong set of the
tide. It is comparatively
shallow here, being only
12 feet at low water, but
as the seawage in on the
surface, it can find its way
through before low-water.
In general the seawage will
take both routes, the wind
determining only the great-
er or less amount each shall
receive.

It was traced by boat to the
eastern end of Bainford Is-
land, but no further for whe-
ther it passed to the right
or left of St. Warren, the
route beyond to the sea is
just the same. It is pre-
sumable from the data of
a few nautical and a study.
of the chart to say the greater portion of it always
passes out between the Fort
and Pemberton. The tide
in strong here and gets much
of the water to the north
of Rainford Island and thus
gets also the sewage com-
ing that way. With a
north wind, as confirmed by
samplers, much of the sewage
will pass to the main chan-
nel by the opening between
St. Warren and Gallup Island.
It was actually found that
a little was forced into the
channel even between Nixey's
mate and Long Island, but
this probably will not occur
often. Hence in general
the sewage may be said to
Pass to the north of St. Warren. The route now having been worked out the dilution proceeding along it will be considered. The sewage at the pumping station contained about 5,000,000 bacteria, which must necessarily vary with the storm water, etc.

In the trunk sewer at entering the tanks the number was 8,000,000 and in the discharge sewer drawing from the tanks it was 10,000,000. These numbers may be a little high as the samples were not planted until 2 hours after taking. Probably there is little error in the sewage stands in the tanks from one high tide to the next.
and in also acted on by the
run. As stated before these
large numbers were relied
upon for tracing the sewage
and the results bear out
very well the inferences.
At 200 yards directly east of
the sewer the sewage was
undiluted to any extent
the number being several
million. At 3/8 of a mile
off this had fallen to 300,000.

About a mile off two samples
were taken one on each side
of a well defined edge and
about 3 feet each way from it.
The sewage water gave 117,000
while the clear water gave
but 900, thus proving undoubt-
edly the strong contrasts at
the edge.
In the gut between Duncanstine Rocks and Bainford Island the number sank to 100,000 and beyond here opposite the middle of the island it was 63,000. A little further it suddenly jumped to 110,000 probably due to a spot of sewage still hanging together. At 300 yards off the south east end of the island the numbers had become 22,000. About the same dilution was noted on the north side of the island. As before static samples were taken no further. On the way back samples were taken to study the discharge from the sort of reservoir above the openings. It showed
that, with a gentle west wind, the sewage had all passed by Long Island 3 hours after the scheduled discharge. A point not fully determined was whether the effect of the sewage pollution could be noted on the back tide. What resemblance bear on this point lead to the conclusion that it cannot be traced. Some taken at the proper time gave numbers of from 300 to 4,000 and there are two how to draw inferences from, since the Neponset and Charles River range in numbers from 20,000 to 30,000, and since the shallow harbor water range from 2 to 4,000.

Having given the amount
of dilution its meaning will be considered. The average number of bacteria for the straight sewage might be stated at 600,000. Near the eastern end of Revere
ford Island this was only 20,000. Hence it would indicate a dilution of the sewage of about 300, that is, that cubic foot of sewage had mixed with 300 cubic feet of salt water. This had taken place only 2½ miles from the outlet and 3 miles further, opposite Boston Light the number of bacteria found would probably be only 6000 or less, thus giving the great dilution of 1 to 1000. The sudden
after passing Ramseyford Is-
land, appears to be due
to the strong tide among the
Quarantine Rocks and about
the point of the island, which
produces eddies that breaks
up the sewage into patches.
This is important for it adds
greatly to the diffusion of
the water reaches the sewage
on all sides.
To realize the dilution that
has taken place it will
be compared with some
figures given by Professor
Baumeister, a German writer.
In a chapter in his book
on sewage he takes up the
pollution of rivers and
considers the question of
the amount of dilution
that sewage must receive
in order to become innoc-
ous, and determines it
from the so-called limiting
value of potable water. This
is based on the organic mat-
ter contained by the sewage,
that is from a chemical not
a bacterial standpoint. Now,
any statements attempting
to give a definite amount
of dilution necessary would
be merely criticised, on ac-
count of the advance in
bacteriology. He says, "If,
moreover, the daily amount
of sewage is assumed to be
about 7 cubic feet per capita,
and the hourly maximum
1/2 of this quantity, then the
conditions for pure water
require about 322 cubic feet of water per day per capita. He adds that the value of potable water can not fixed on the assumption that part of the organic matter was from excrement and hence that definite value could not be assigned. However, from a chemical point of view the organic matter is about the same from whatever source. It is this view that, if the sewage has received far more dilution than is necessary, from a chemical point of view, to produce a drinking water, there could be no chance of producing a nuisance or even of noticing
sit in the lower part of the harbor.

A last point to be considered is the effect of the salt water on the bacteria occurring in fresh water. Prof. Russell said that undoubtedly this far greater proportion of bacteria coming in with sewage, river water etc. must necessarily perish on account of the changed character of the medium in which they must live, though probably some accommodate themselves to the changed condition and survive, becoming adventive forms. It is probably true that some species may be affected, but, from
experiment, it does not appear to be at all general. When sewage is planted in fresh water, the number rise slowly for a day or two and then suddenly increases to several million. It remains at this point for a long time and then slowly falls off, taking perhaps months for the whole process. The same experiment repeated with salt water shows the same curve of rise and about the same numbers. It cannot be said how long they will remain the same as the length of time required would not permit the experiment. Results showed however, that for over a
with the buoy character has little or no effect whatever on the bacteria.

In conclusion it may be said that no objections have arisen, as far as studied, that can be urged against the disposal by sea of the sewage. There is some smell at Moon Island, but, with the building of a sea wall from the outlet to the end of the island, this, even, will largely disappear for it comes to some extent from the deposits on the shore just off the river outlet.

The results show that far larger quantities of sewage might be discharged and that
the high rate of dilution would still be maintained, for there must be a large over-turning of the harbor water at every tide, that is, that an immense amount of sea water must take the place of the polluted water, the latter passing out to sea and disappearing. The method of disposal appears to be good both in detail and in the conveyance out to sea of the sewage and its final complete mingling there.

Many thanks are due Mr. Wells, Superintendent of Streets; Mr. Lawer, Superintendent of Sewers;
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tees and privileges to me in connection with the work and enabled me to carry much of it to a conclusion.