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Executive Summary

of the

Environmental Transmission of

Norovirus into Oysters

following the 2016 / 2017 national outbreak of norovirus linked to the consumption of BC oysters

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This report represents the general opinion of the working group, and may not necessarily reflect individual opinions of working group members or the opinions or policies of agencies

Any questions may be directed to fpinfo@bccdc.ca

Agencies who participated in this working group are gratefully acknowledged and include:

- Alberta Health Services
- BC Centre for Disease Control
- BC Ministry of Agriculture
- BC Ministry of Environment
- BC Ministry of Health
- BC Shellfish Growers Association
- Canadian Food Inspection Agency
- Centre for Coastal Health
- Department of Fisheries and Oceans
- Environment and Climate Change Canada
- First Nations Health Authority
- Health Canada
- Indigenous Northern Affairs Canada
- Public Health Agency of Canada
- Vancouver Island Health Authority
- Washington State Department of Health

EXECUTIVE SUMMARY

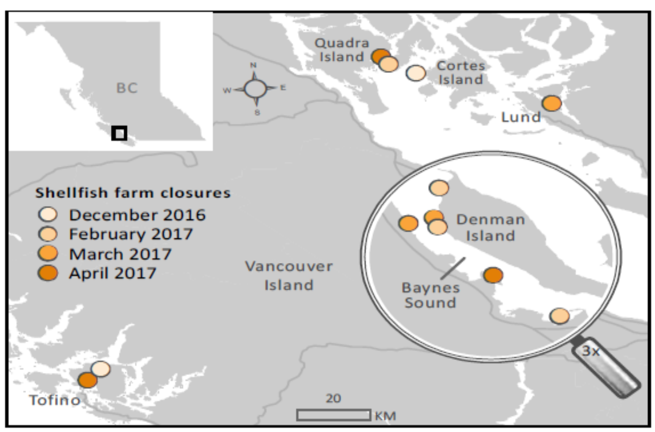
Norovirus is a highly contagious virus that causes vomiting and diarrhea. While it is most commonly spread person-to-person, illness may also occur from consuming contaminated food or water (1). It is a resilient virus with a hard outer shell, and under favorable environmental conditions is able to survive for several months in water and several weeks on surfaces (2).

In November 2016, a norovirus outbreak linked to BC harvested oysters began. The outbreak affected more than 400 Canadians over six months; it was declared over on May 11th 2017 (3). Under the umbrella of the national Outbreak Investigation Coordination Committee, a working group was formed to explore potential causes of environmental norovirus contamination in the growing waters of oysters (Environmental Transmission of Norovirus to Oysters working group, Box 1).[1] Knowledgeable specialists from multiple disciplines including environment, fisheries, public health, regulators and shellfish industry farm owners and managers were invited to provide expert opinion. Experts from outside the working group provided information on specific topics to assist the working group discussions. The purpose of the group was to identify plausible sources of environmental norovirus contamination that may have led to this outbreak in order to mitigate risk of future illness.

Box 1. Environmental Transmission of Norovirus in Oysters Working Group Members

1. BC Centre for Disease Control
2. BC Provincial Ministry of Environment
3. BC Provincial Ministry of Agriculture
4. BC Provincial Ministry of Health
5. BC Shellfish Growers' Association
6. Canadian Food Inspection Agency
7. Environment and Climate Change Canada
8. Fisheries and Oceans Canada
9. Health Canada
10. Public Health Agency of Canada
11. Regional BC Health Authorities
12. Washington State Department of Health
13. Invited experts from the University of British Columbia, Centre for Coastal Health, Alberta Health Services, Applied Science Technologists & Technicians of BC and others

During this prolonged outbreak, 12 BC shellfish farms were closed. All farms were epidemiologically linked to norovirus illnesses. Tests of oysters from some of the implicated farms demonstrated contamination with norovirus, *E. coli* and/or elevated coliphage which is an indicator for enteric virus (see map). Economic losses to the shellfish industry arising from this outbreak were substantial ($9.1 million).



[1] Terms of reference for and roles and responsibilities of working group members can be found in Appendices 1 and 2.

BC was not the only location on the Pacific Northwest coast affected. Washington State also reported over 200 norovirus-like illnesses linked to more than a dozen Washington shellfish harvest sites – although the majority of illnesses traced back to a single growing area (4). Between December 2016 and April 2017, there were 145 separate case and case clusters of illnesses reported in Canada, and 49 case and case clusters reported in Washington State (3, 4).

The working group generated a list of plausible hypotheses for the environmental transmission of norovirus into oysters (summarized in Box 2) and gathered available evidence for and against each hypothesis.

Box 2. Summary of transmission pathways of norovirus into the environment

- Local and metropolitan waste-water treatment plant effluent (including system overflows)
- Land run-off and septic system discharges (including overflows from agricultural and community sources)
- Other sewage outfalls
- Discharge from boats and vessels (commercial, recreational, cruise ships, ferries)
- Wildlife (sea lions on shellfish docks)
- Movement (relay) of contaminated shellstock to a clean area
- Ill shellfish farm workers and/or floathomes or floatcamps
- Wet-storage and processing plants
- Distributors, restaurants and retailers

Hypotheses were developed, based on knowledge of previous oyster and shellfish contamination events, and the expert opinions of working group members. The quality of evidence as to plausible source ranged from strong, i.e., direct evidence definitively proving or disproving the hypothesis, to weak i.e., indirect evidence or opinion suggesting that the hypothesis may be more or less likely. Evidence was examined as it related specifically to the 2016-2017 outbreak and, more generally, to the potential of the hypothesis as a source of contamination in BC shellfish. Arguments for and against each hypothesis were developed based on evidence collected through group discussion, expert opinion, literature review and included examination of data that informed the outbreak and working group investigations.

The working group activities included stakeholder surveys, in-depth literature reviews of specific topics, consultation with scientific and professional experts, collection and evaluation of supporting evidence, analysis of environmental parameters, sewage sources and consensus building discussions. Evidence gaps and research needed to fully evaluate these hypotheses were also discussed. Thirty evidence gaps were identified that hindered our ability to fully assess the plausible hypotheses. Evidence gaps and associated barriers were noted for:

- mapping,
- assessments of various sewage sources,
- baseline data,
- norovirus and indicator testing methods,
- norovirus behaviour in marine environments, and
- epidemiological assessments.

Members were challenged by a lack of information, or where information existed, by barriers that made acquisition and interpretation of that information impossible. A status evaluation of the evidence gaps found 18% were completed and 38% were in progress by November 2017. However, for the majority of evidence gaps (43%), the working group did not know from whom to request information or agencies had no mandate or had not yet explored how to address the gap.

Working group discussions found multiple sources of human sewage contamination of the marine environment the most plausible explanation for norovirus contamination of shellfish farms. Two pieces of evidence support this conclusion.

❶ **The only way for a human to be infected by norovirus is through exposure to feces or vomit of another infected human.** Exposure to as few as 10 norovirus particles can cause illness (5). Norovirus is species—specific: only human strains of norovirus cause illness in humans. Although different strains of norovirus infect animals, evidence so far suggests these strains do not infect humans (6, 7). Animals are not infected by human norovirus, and will not amplify human norovirus even if they are exposed to it.

How did norovirus contaminate so many different shellfish farms?

Human sewage contamination of the marine environment.

Photos of sea lions adjacent to norovirus-contaminated oyster farms suggested the mammals as a plausible source; however, this hypothesis was ruled out based on direct evidence (testing of sea-lion scat in BC was negative for human norovirus) and literature review.

❷ **A single contamination event cannot explain the geographic distribution observed.** BC has linked previous norovirus shellfish illnesses to point-source contamination events in the past. In 2010, norovirus illnesses were linked to overboard discharge and dumping from a boat into one shellfish bed (8). By contrast, in 2016-17, despite an exhaustive investigation of possible pollution sources, no major issues were identified along the coastlines where farms operated (9). Two minor issues were noted during the outbreak period, but neither occurred prior to the first occurrence of illnesses linked to oysters. These minor issues included a waste-water discharge >20 km away from an oyster farm, and the sighting of commercial fishing vessels in early March. Both issues could potentially have contributed to marine water contamination, and the ongoing illnesses but neither would explain earlier contamination.

In the Baynes Sound area where the majority of shellfish farms linked to norovirus illnesses were located, from December onwards, there were no significant point-source contamination events that would explain the wide-spread contamination.

Actively feeding oysters can filter up to 10 litres of water per hour and will bind norovirus to their tissues (10, 11). During the winter norovirus season and because norovirus is a common disease estimated to cause 3 to 4 million illnesses annually in Canada, **all sewage discharge sources are expected to contain norovirus:** *between one to ten thousand norovirus particles per litre of water* (12)

Human sewage contamination of the environment from multiple sources is thus the most plausible reason for shellfish farm contamination and norovirus presence in oysters.

A third piece of evidence supports why norovirus, known to be present in human sewage, was able to survive in the marine environment and spread to shellfish farms in the fall of 2016 and winter of 2017.

❸ **Climate conditions affect survival of this virus. Heavy rainfall, low sunlight conditions[2], down-welling[3] and colder than normal temperatures** allowed norovirus to persist in marine waters for extended periods (13). Norovirus is seasonal: most norovirus illnesses in North America occur in the winter (14). The 2016-17 season had a near-record rainfall event in November during the same month as the Tofino oyster festival where 118 people became ill (15). Temperatures were 2°C colder than average between December 2016 and February 2017 (15). Norovirus also survives longer in water of lower salinity (16). During extreme rainfall events, fresh-water currents floating on top of ocean water have the ability to carry marine viruses long distances. While few studies have been published on how far norovirus can travel from a source of pollution, norovirus has been detected 24 kilometres away from a sewage outfall in New Zealand (17). A United Kingdom study found norovirus levels able to cause illness in a shellfish site characterized by poor marine flushing shellfish and detectable norovirus levels in an open ocean shellfish site, both ten kilometres distant from sewage sources (18). Environmental conditions in BC in 2016-17 contributed to the widespread norovirus (sewage) contamination of the marine environment and oyster growing areas.

What caused the outbreak? Where did the human sewage contamination come from?

In BC, the most plausible sources of human sewage contamination (Box 3) are those nearest to the shellfish farms, although we were unable to rule out contamination from more distant sources. Other countries have shown norovirus levels nearer to waste-water treatment plants create a significant threat for shellfish farms and water quality (13, 19-21).

Box 3. Potential sewage sources impacting shellfish growing areas

<u>Near to shellfish farm locations</u>

- Septic seepage from private homeowners
- Local waste-water treatment plants, lagoons
- Sewerage overflow events from combined water/sewer drainage
- Discharge from commercial and recreational vessels
- Float-homes and float-camps

<u>Distant to shellfish farm locations</u>

- Metropolitan waste-water treatment plant effluent discharges

The greatest conceptual challenge was looking for a single transmission pathway to explain the outbreak.
While a single reason would be convenient,
the working group concluded that multiple sewage sources discharging under environmental conditions favourable to norovirus preservation most likely contributed to shellfish farm contamination.

[2] Strength and duration of sunlight, including ultraviolet light, is lower in the winter due to the angle of the earth relative to the sun. Incidence of rays is lessened, therefore less energy and penetration into marine waters allows for longer virus survival. Combined with cloud layer we called this low sunlight conditions.
[3] Downwelling is when wind and earth's rotation move surface water toward coastlines; upwelling is when surface waters are moved away from the coast.

We cannot fully explain the events of 2016-17: there remains uncertainty why some farms were affected while others were not, or why no norovirus illnesses were reported in other years with similar weather conditions. It remains unclear whether metropolitan waste-water treatment plants effluents[4] containing norovirus could affect distant oyster growing areas, although environmental conditions present during 2016-17 may explain how norovirus survived and why both near and distant sources of norovirus could have impacted shellfish farms.

Looking forward: solutions needed

This norovirus outbreak was not unique. A similar norovirus outbreak linked to oysters harvested from geographically dispersed farms in BC occurred in 2004. **To prevent contamination of oysters with norovirus we must control the amount of raw untreated human sewage entering the marine environment**. This will require multiple actions from multiple stakeholders at all levels of engagement: at community and government levels, with regulators, politicians, engineers, scientists and educators. The health of the public and the future of marine shellfish farming and wild harvesting is at risk from human sewage pollution. What occurred in the 2016-17 season will occur again — the only question is when. More action is required to address this public and environmental health issue immediately.

In summary, multiple sources of human sewage entering the marine environment were identified as the most plausible reason for oysters becoming contaminated with norovirus. The outbreak likely occurred in 2016-17 because environmental conditions allowed norovirus present in sewage sources entering the marine environment to be transported to shellfish farms, and to survive and accumulate in oysters.

[4] Metropolitan waste-water treatment plants were defined as plants near to urban areas and distant (>20 km away) from shellfish farms, e.g., plants located in Vancouver and Victoria.

References for Executive Summary

1. Atmar RL, Estes MK. The epidemiologic and clinical importance of norovirus infection. Gastroenterol Clin North Am. 2006;35(2):275-90.
2. Kotwal G, Cannon JL. Environmental persistence and transfer of enteric viruses. Curr Opin Virol. 2014;4:37-43.
3. Public Health Agency of Canada. Public Health Notice – Ongoing outbreak of norovirus and gastrointestinal illnesses linked to raw and undercooked oysters from British Columbia 2017. Ottawa, ON:PHAC. 2017. Available from: http://www.phac-aspc.gc.ca/phn-asp/2017/outbreak-norovirus-eclosion-eng.php.
4. Nixon MR. Washington State Department of Health norovirus information, pers. comm. by e-mail to L. McIntyre. 2017.
5. Teunis PFM, Moe CL, Liu P, E. Miller S, Lindesmith L, Baric RS, et al. Norwalk virus: how infectious is it? J Med Virol. 2008;80(8):1468-76.
6. Cortes-Penfield NW, Ramani S, Estes MK, Atmar RL. Prospects and challenges in the development of a norovirus vaccine. Clin Ther.39(8):1537-49.
7. van Beek J, de Graaf M, Al-Hello H, Allen DJ, Ambert-Balay K, Botteldoorn N, et al. Molecular surveillance of norovirus, 2005–16: an epidemiological analysis of data collected from the NoroNet network. Lancet Infect Dis. 2018(Jan 25).
8. McIntyre L, Galanis E, Mattison K, Mykytczuk O, Buenaventura E, Wong J, et al. Multiple clusters of norovirus among shellfish consumers linked to symptomatic oyster harvesters. J Food Prot. 2012;75(9):1715-20.
9. Environment and Climate Change Canada. Summary of ECCC pollution source investigtions and water quality in proximity of emergency closure areas. Report to the Pacific Region Interdepartmental Shellfish Committee (PRISC). Vancouver, BC:ECCC. 2017 (Apr 27), p. 16.
10. Loosanoff VL. Some aspects of behavior of oysters at different temperatures. Biological Bulletin (Lancaster).1058:114(1):57-70.
11. Le Guyader FS, Loisy F, Atmar RL, Hutson AM, Estes MK, Ruvoen-Clouet N, et al. Norwalk virus-specific binding to oyster digestive tissues. Emerg Infect Dis. 2006;12(6):931-6.
12. Pouillot R, Van Doren JM, Woods J, Plante D, Smith M, Goblick G, et al. Meta-analysis of the reduction of norovirus and male-specific coliphage concentrations in wastewater treatment plants. Appl Environ Microbiol. 2015;81(14):4669-81.
13. Campos CJ, Kershaw S, Morgan OC, Lees DN. Risk factors for norovirus contamination of shellfish water catchments in England and Wales. Int J Food Microbiol. 2017;241:318-24.
14. Ahmed SM, Lopman BA, Levy K. A systematic review and meta-analysis of the global seasonality of norovirus. PLoS One. 2013;8(10):e75922.
15. West G. Presentation to Environmental Transmission of Norovirus into Oysters (ETNO) group April 13, 2017: potential weather factors in norovirus outbreaks, Vancouver, BC: University of British Columbia, Weather Forecast Research Team; 2017.
16. Wang J, Deng ZQ. Modeling and prediction of oyster norovirus outbreaks along Gulf of Mexico coast. Environ Health Perspect. 2016;124(5):627-33.
17. Campos CJ, Lees DN. Environmental transmission of human noroviruses in shellfish waters. Appl Environ Microbiol. 2014;80(12):3552-61.
18. Campos CJA, Goblick G, Lee R, Wittamore K, Lees DN. Determining the zone of impact of norovirus contamination in shellfish production areas through microbiological monitoring and hydrographic analysis. Water Res. 2017;124:556-65.
19. Sterk A, de Man H, Schijven JF, de Nijs T, de Roda Husman AM. Climate change impact on infection risks during bathing downstream of sewage emissions from CSOs or WWTPs. Water Res. 2016;105:11-21.
20. Campos CJA, Avant J, Lowther J, Till D, Lees DN. Human norovirus in untreated sewage and effluents from primary, secondary and tertiary treatment processes. Water Res. 2016;103:224-32.
21. Winterbourn JB, Clements K, Lowther JA, Malham SK, McDonald JE, Jones DL. Use of *Mytilus edulis* biosentinels to investigate spatial patterns of norovirus and faecal indicator organism contamination around coastal sewage discharges. Water Res. 2016;105:241-50.