Proceedings of the Food Standards Agency’s Foodborne Viruses Research Conference

Held on Tuesday 15th and Wednesday 16th January 2013
Holiday Inn London Bloomsbury, London
INTRODUCTION

Tackling norovirus under the Foodborne Disease Strategy 2010-2015

The Foodborne Disease Strategy (FDS) 2010-2015\(^1\) aims to deliver key parts of Outcomes of the Food Standards Agency (FSA) overall strategy for 2010-2015. These include:

- **Outcome 1:** Food produced or sold in the UK is safe to eat
  - *Reduce foodborne disease using a target approach*

- **Outcome 4:** Consumers have the information and understanding they need to make informed choices about where and what they eat
  - *Improve public awareness and use messages about good food hygiene practices at home*

Following a Food Chain Analysis project and consultation process with key stakeholders, *Campylobacter, Listeria* and norovirus were identified as key pathogens of focus for the FDS in 2010-2015. While Risk Management Programmes have been established for the two bacterial pathogens, further research is required before an evidence-based norovirus Risk Management Programme can be developed. It is for this reason that the FSA hosted a conference on Foodborne Viruses research, held in London on 15\(^{th}\) and 16\(^{th}\) January 2013 (See Annex).

The foodborne virus research conference focussed mainly on norovirus because of its importance in gastrointestinal illness and its association with foodborne transmission routes. The aim of the conference was to gather existing knowledge and identify key areas in which further foodborne virus research is required. The meeting brought together participants from the UK, EU and wider international community. This included leading researchers and experts in norovirus, hepatitis A and E, representatives from industry, retailers, regulators and other government organisations. The current understanding of norovirus in the UK and overseas was presented and the invited delegates identified knowledge gaps the FSA and other funders needed to consider for further research.

**Welcome and purpose of the conference**

Dr Andrew Wadge, Food Standards Agency Chief Scientist

The event was opened by FSA Chief Scientist, Andrew Wadge who described the two day conference as “very timely” following significant media coverage of “winter vomiting bug”, with one even describing norovirus as the “Ferrari of the virus world”. The FSA estimates that there are around one million cases of foodborne illness in the UK each year with 20,000 hospitalisations and 500 deaths\(^2\). Viruses, in particular

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\(^1\) http://www.food.gov.uk/multimedia/pdfs/fds2015.pdf
\(^2\) http://www.food.gov.uk/multimedia/pdfs/publication/csar1112.pdf
norovirus, play a significant part in contributing to the overall burden of foodborne illness and are therefore an important area to address.

Andrew highlighted that in recent years, foodborne norovirus has been linked to some significant sometimes large foodborne outbreaks, citing a recent outbreak in Germany affecting approximately 11,000 people that was linked to frozen strawberries as an example. The purpose of the conference was to increase our understanding of norovirus and other foodborne viruses, namely hepatitis A and E, in the food chain and to identify the research priorities that need to be addressed by the Agency or in partnership with industry/other funders to underpin measures to control them in the food chain. A number of strategies are in place within the FSAs Foodborne Disease Strategy (FDS) and other programmes to address the key bacterial pathogens which contribute significantly to foodborne illness in the UK: the outputs of this conference will help the FSA in developing its foodborne virus research programme, which in turn would inform a future foodborne viruses risk management programme.

UK publicly funded research on foodborne viruses and feedback on the pre-conference questionnaire
Dr Paul Cook, Food Standards Agency

Paul Cook, Head of Microbiological Food Safety branch, outlined the findings of the 2005 Microbiological Safety of Food Funders Group report on foodborne viruses and highlighted the research gaps identified at the time. Since that report, there has been an increase in the number of new publically funded research projects on foodborne viruses for 2005-2012 (see Annex 1 for list of projects) and by an increasing number of funders. The FSA had also recently placed a research call to assess the contribution made by the food chain to the burden of UK-acquired norovirus infection.

Paul summarised the findings of the pre-conference questionnaire that delegates completed during the registration process. Delegates were asked to estimate the proportion of UK-acquired norovirus illness which they considered to be foodborne (see Figure 1). Eighty seven delegates provided a response to this question; with the majority (40%) believing that between 10 and 29% of UK-acquired norovirus illness was foodborne. Seventeen percent thought that less than 10% of norovirus illness was foodborne whereas 26% were unsure. Delegates were also asked to provide justification/reason for their choice for which the most common were:

- Person-to-person transmission the main transmission route
- Surveillance data (e.g. outbreaks)
- Difficult to separate contributions of sources.

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Delegates were asked for their opinions on the biggest limitations in terms of controlling norovirus. The limitations identified by the delegates were:

- Lack of proven effective interventions in the food chain
- Inability to establish methods for culturing norovirus in vitro
- Difficulties in distinguishing infectious and non-infectious norovirus in samples using PCR-based detection methods
- Lack of an agreed “acceptable limit”

In addition to norovirus, delegates felt that hepatitis A and E were also important viruses which required further consideration (addressed later in the conference).

Prior to the conference, the 87 delegates were asked where the FSA should focus its efforts regarding potential interventions for reducing norovirus in the food chain (see Figure 2). Thirty nine percent of the delegates thought that intervention should target food handlers, followed by shellfish at pre-harvest (21%) and at harvest (17%). However by the end of the first day of the conference, the delegates had overwhelmingly changed their mind with 83% (63 out of 76) of the delegates believing that interventions should focus on food handlers (See Figure 2).
When completing the pre-conference questionnaire, delegates felt that several research knowledge gaps regarding norovirus needed to be prioritised. These included:

- Contribution of the foodchain to norovirus
- Norovirus contamination by infected food handlers
- Contribution of different foods to infections
- Effectiveness/improvement of shellfish depuration.

UNDERSTANDING NOROVIRUS

What is norovirus?
Professor David Brown, Health Protection Agency

David Brown gave an overview of norovirus describing the key clinical features, the current status of norovirus virology and diversity in investigating the burden of foodborne illness. He indicated that there are 3 million cases in the community each year, costing hospitals in excess of £100 million per annum. Foodborne transmission was likely to occur directly through food vehicles such as bivalve molluscs and soft fruit, through contaminated food handlers and preparation surfaces. However, the scale of foodborne transmission is poorly defined.
Noroviruses cause an acute self-limiting gastroenteritis and are characterised by frequent vomiting, abdominal cramps and diarrhoea. The Kaplan Criteria, used to determine norovirus outbreaks, describes a short incubation period between 15 and 48 hours with symptoms lasting from 12 to 60 hours. Vomiting was evident in greater than 50% of symptomatic patients and both patients and staff were affected. Viral shedding of 3-4 weeks is common.

By using reverse transcriptase polymerase chain reaction (RT-PCR) rather than electron microscopy to detect norovirus, an increase in the diagnosis of norovirus infection was evident. However, to successfully diagnose norovirus-associated infectious intestinal disease using viral load, low cycle threshold (Ct) values were used as a cut-off as the viral load decreased with increasing Ct value.

In a virus challenge study, half of all volunteers who were first challenged with Norwalk virus (now referred to as norovirus) experienced clinical illness. Upon exposure to Norwalk virus for a second time 28-42 months later these same individuals went on to experience clinical illness. Interestingly however, 3 of the 4 volunteers who returned to be exposed to Norwalk virus for a third time 4-8 weeks later failed to develop clinical illness suggesting a very short-lived immunity.

A likely explanation is that norovirus genotype II genotype 4 (GII.4) strains appear to evolve in a similar way to influenza with herd immunity driving antigenic change, together with mutations in the viral binding proteins. The error prone nature of RNA replication leads to accumulation of point mutations and the emergence of variant strains. Even still, prototype vaccines are in development, designed against GI.1 strain and homologous challenge showed some protection, but usable vaccines are not yet within view.

Of the 25 genotypes of norovirus recognised, GII.4 is the predominant type, associated with >80% of outbreaks recognised worldwide. In healthcare settings, norovirus outbreaks have a unique winter peak, compared to other settings. More recently, norovirus genotype profiles have been used to differentiate between origins of foodborne outbreaks and it is anticipated that new techniques such as next generation sequencing may contribute to understanding the burden of foodborne viruses.

Clarification point

In response to the presentation, a delegate queried whether those individuals exposed twice to norovirus who did not get ill were either immune to certain genotypes or would never get norovirus. It was clarified that the volunteer study on Norwalk virus had a narrow range, for example Norwalk virus GII.4. However, the principle that some people are not susceptible to different types or norovirus was established.
**Norovirus: Outbreaks in the hospital setting**
Professor Jim Gray, Norfolk and Norwich University Hospital (NNUH)

Jim Gray presented data demonstrating a continual increase in laboratory reports of norovirus from 2002 to 2010, although some of the increase observed could actually be explained by an improvement in detection methods. More and more outbreaks are being investigated and most relate to hospitals and car home settings, with GII.4 being the predominant genotype.

Norovirus is highly infectious with high attack rates among hospital patients and staff. There are multiple routes for introducing norovirus into hospitals by sick patients, visitors and staff via person-to-person transmission but also through ingestion of contaminated food and by contact with contaminated environmental surfaces. Norovirus is also stable in the environment as it is highly resistant to many disinfectants and can survive temperatures up to 70°C. In addition the virus may be protected by the matrix of faeces or vomit. This makes it difficult to remove norovirus once it is introduced into a hospital ward.

Analysis of norovirus outbreaks in 2010 at Norfolk and Norwich University Hospital revealed that eight distinct genetic clusters of GII.4 were circulating or co-circulating in the hospital. Some clusters were found up to 34 days after the last report. An explanation for this could be asymptomatic carriage, chronic excretion or even environmental contamination. In order to determine survival of norovirus in the environment, surfaces were screened and in 2011 when an outbreak occurred in one particular ward of the hospital, norovirus was detected on almost 50% of every surface screened.

To reduce the risk of spread in the hospital environment, current procedures in place are clean and disinfect, to close bays/wards and an emphasis on hand washing with soap and warm water. Possible explanations as to why we were seeing increases in outbreaks were that hospital environments were more difficult to clean, more complex equipment existed and higher bed occupancy rates occurred.

**The second study of infectious intestinal disease in the UK (IID2 study)**
Professor Sarah J O’Brien, University of Liverpool

Sarah O’Brien gave a presentation on the second study of infectious intestinal disease in the community (IID2 study). The main aim of this study was to establish whether the incidence of IID in the community had changed since the first IID study was carried out in the mid 1990s. It was noted at the outset that the cases of IID reported to national surveillance were a fraction of actual cases.

In order to determine the number of IID cases, a series of studies was conducted with clear case definitions. IID was defined as people with loose stools or clinically significant vomiting, lasting less than two weeks, in the absence of a known non-infectious cause and preceded by a symptom-free period of three weeks. Molecular testing of samples for selected targets was performed. These targets included: norovirus, sapovirus and rotavirus. Patients with terminal illness, severe mental capacity, non-infectious causes of diarrhoea and patients whose first language was
not English and for whom a suitable interpreter was not available were all excluded from the study.

Positive laboratory results for norovirus were determined by quantitative PCR with a cycle threshold (Ct) value of less than 30 considered to be positive. From a cohort study it was estimated that IID affected approximately 1 in 4 members of the population annually. Approximately, 17 million people were affected each year in the UK (equivalent of 25% of UK population), resulting in a minimum of 19 million absences from work or school. For every case of IID reported to national surveillance it was estimated that there was a further 147 cases in the community.

Norovirus was the most commonly identified pathogen causing IID in the community and resulted in nearly 3 million cases. For every case of norovirus reported to national surveillance there was estimated a further 315 cases in the community which go unreported. When comparing the aetiology of IID1 and IID2 studies, in both community and GP presentation cases, there was an increase in norovirus in IID2. It was suggested that as a next step, there is a need to estimate the contribution of norovirus to the overall burden of foodborne disease.

The final report for project FS231043: ‘The second study of infectious intestinal disease in the community (IID2 study)’ is available on the FSA website at http://www.foodbase.org.uk/results.php?f_report_id=711

Modelling the foodborne transmission mechanisms for norovirus
Professor David C Lane, Henley Business School

David Lane explained that previous epidemiological modelling of norovirus treats established human categories (susceptible, exposed, infectious etc.) and represents the person-to-person mechanisms of transmission. Foodborne transmission was present as only an exogenous factor. This presentation reports on work conducted for the FSA (project FS241027) which models the main foodborne effects. This allows the underlying mechanisms (including delay and reservoir effects) to be represented, the disaggregation of the constituent factors which make parameter estimation possible, and the identification of parameters representing changes to human behaviour (and their effects on norovirus prevalence).

The work has two parts. The first reports on a complex epidemiological model created within the System Dynamics Modelling methodology which represents: bivalve shellfish production and consumption; sludge usage on crops; and subsequent stages of food production for salad vegetables and soft fruit. The food production sub-system represents activities such as harvesting, processing and handling before final use in both catering and home settings. These activities relate to human norovirus prevalence via the transmission of norovirus genome copies into sewage or via direct human to food contact. These effects themselves then feed back into the person-to-person sub-system as additional, now endogenous, transmission effects. This model provides a conceptual framework for these foodborne effects, including associated parameter values. These parameters fall into three categories: known; capable of judgemental estimation; and capable of establishment via appropriate research. The model therefore provides an organising framework for subsequent discussion and
research relating to foodborne norovirus transmission, as well as discussions regarding how interventions (e.g. controls along the food chain, or advice to consumers) might change the prevalence of norovirus in the UK population.

The second part reports the mathematical analysis of the existing but recalibrated person-to-person model. The recalibration uses data from an extension to the second study of infectious intestinal disease in the community (IID2 Study), which estimated the burden of UK-acquired foodborne disease. This allows consideration of different strengths of foodborne transmission which then indicates the quantitative impact on norovirus prevalence of changing behaviour in the foodborne mechanisms. This work therefore provides an estimate of the extent to which norovirus infections in the UK might, in principle, be influenceable via changes in food production methods and human behaviour.

**Interactive discussion - Understanding norovirus**

Following on from the presentations, an interactive discussion was held where the delegates were asked to consider the following questions:

a) What do you believe is the main source of norovirus?

b) There seems to be a higher incidence of norovirus in the winter, why is this?

The main gap identified by delegates was uncertainty about the source of norovirus. Sources suggested were hand contact surfaces, children, infected food handlers and person-to-person infection. The routes of norovirus transmission are both multiple and complex. As the virus circulates from humans to the environment; from the environment to food; and then back in to humans, it was difficult to identify the main route of contamination onto food and where this cycle could be broken. Additionally, it was highlighted that the relative contribution of different food types to the overall incidence of foodborne norovirus in the community is unknown and until this is addressed it is very difficult to direct effective interventions. Furthermore, what are the major food stuffs that we need to concentrate on and tackle and what is the contribution of food handlers.

On the issue of seasonality, delegates suggested a number of possible reasons why there was an increase in norovirus reports during colder months (October to February). Amongst the suggestions were:

- That people generally tended to remain indoors and as a result this presented an opportunity for increased person-to-person spread
- Less sunlight/UV light during the winter compared to warmer months. The reduced UV levels during the colder month may lead to norovirus surviving in greater levels in environmental reservoirs
- We know norovirus can be present in oysters even though they are not considered the definitive source, and that levels detected in oysters tend to be higher during winter. Do higher levels in oysters in winter serve to propagate infections, following initial contamination of the oysters from human waste; effectively creating a positive feedback cycle?
- If our immune system more challenged in winter months generally, it was suggested that this might make us more susceptible to norovirus infections.
Are people less inclined to observe good hygiene practices in winter months? For example are people less inclined to wash their hands due to cold temperatures, especially if water temperature is also cold?

The question was raised whether seasonality was seen in other countries in a similar pattern, i.e. in tropical countries where there are no seasons, is there still a peak and do countries in the southern hemisphere, observe a peak in their winter?

NOROVIRUS METHODOLOGY

Norovirus detection methods
Dr David Lees, Centre for Environment, Fisheries and Aquaculture Science (Cefas)

David Lees described work conducted in the European Union developing a standard reference method for the detection of norovirus and hepatitis A virus in foods suitable for use as part of EU food legislation. The need for the development of reliable methods was due to differences in outcomes/results. The European Union Reference Laboratory (EURL) conducted proficiency testing for norovirus and hepatitis A virus detection in molluscs and revealed the use of several different methods of virus and RNA extraction. In addition all permutations of the PCR format were employed. As a result, performance was variable and some laboratories even failed to detect norovirus in an oyster sample responsible for a large international outbreak of norovirus gastroenteritis. This analysis suggested a more standardised approach would lead to better performance.

To establish standardised methods, the European Committee for Standardisation (CEN) tasked the technical advisory group (comprised of European food and water virology experts) with the development of a standard detection method for viruses in foodstuffs. This had to be a horizontal method that would include the detection primarily of norovirus and hepatitis A virus mainly in salad crops, soft fruits, bivalve shellfish, bottled water and on hard surfaces. Detection was confirmed by real-time RT-PCR with probe confirmation and a standard was developed with both quantitative and qualitative parts. The methods chosen were agreed by consensus within the technical advisory group supported by comparative evaluations, and decisions were informed by objective evidence such as published methodologies and ISO recommendations.

The established protocol covers how viruses are extracted from different matrices, how RNA is subsequently extracted, real-time RT-PCR and result interpretation. In a ring trial performance, laboratories using the standardised methodology performed better in correctly identifying viruses than those using alternative methods. The publication of the technical specification is due early 2013.
A critical review of methods for detecting human noroviruses and predicting their infectivity
Dr Angus Knight, Leatherhead Food Research

Angus Knight provided details of a FSA funded critical review (project FS101036) which aimed to identify methods used to detect norovirus in food, the environment and in clinical samples and to predict their infectivity. Whilst reverse transcription quantitative PCR (RT-qPCR) is the most widely used method to detect human norovirus, prediction of infectivity requires differentiation of RT-qPCR signals derived from: intact infective virus, intact defective virus, ribonucleoprotein complexes, naked RNA and non-specific signals.

In the absence of a simple and efficient human norovirus culture system, there is a dilemma in assessing the risk to human health from samples positive in RT-qPCR assays. For example, if a virus capsid was damaged, the virus would be inactivated, however, RNA would still be quantifiable by RT-qPCR. To overcome this, capsid integrity assays measure the exposure of RNA only from intact virus particles which are presumed infectious. This method applies to the whole population of virus particles and not just the measured “infective” fraction. Sample pre-treatment therefore allows differentiation of these RT-qPCR signals. However, the capsid integrity assay does not measure any loss of infectivity owing to loss of receptor recognition.

In order to solve the problem of RT-qPCR signals from “defective” intact particles resulting from receptor damage, receptor integrity assays can be conducted using various receptor binding ligands. The receptor binding can then be measured by RT-qPCR. However, this assay has the difficulty in identifying actual human norovirus receptor and does not consider use of alternative receptors. In addition it may not detect completely inactivated particles. Capsid integrity assays can allow differentiation of RT-qPCR signals from intact particles; however these assays cannot detect genomic damage.

Loss of genomic integrity may also contribute to loss of infectivity. A single strand breaks to genomic RNA are sufficient to abolish infectivity but are not detected by RT-qPCR owing to the small size of the RT-qPCR amplicon. Long RT-qPCR assays can be used to detect these single strand breaks RNA, however this can result in less efficient detection. The relative importance of capsid and genomic integrity to virus survival in the environment is not known. It is not known if these assays can be applied to complement existing CEN methods.

For example, long RT-qPCR assays may be used to differentiate intact from degraded genomic RNA, however this can be difficult. Additionally, single strand breaks are not detected by small fragment RT-qPCR.

In conclusion, whilst capsid integrity assays can allow differentiation of RT-qPCR signals from intact particles, these assays cannot detect genomic damage. The relative importance of capsid and genomic integrity to virus survival in the environment is not known. Additionally, it is not known whether capsid integrity assays can be applied to CEN methods?

**A systematic review of the survival of norovirus in foods and on food contact surfaces**

Dr Angus Knight, Leatherhead Food Research

In the second of his presentations, Angus explained that the FSA is funding a systematic review (FS241043) which was designed to answer a specific defined question “What are the natural norovirus persistence characteristics in food and the environment, and how these properties can be altered by applying physical and/or chemical treatments to foods or food contact surfaces”. To do this, the review would follow the Preferred reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines which were established to standardise the systematic process and allow the success of interventions to be evaluated. This study is on-going and due to be completed in summer 2013.

**Interactive discussion - Norovirus methodology**

During the discussions, delegates were asked to consider the following questions:

a) What are the limitations of current detection methods?

b) How to overcome the limitations?

c) What do you believe are the research gaps in this area?

A delegate raised the point that the current norovirus detection methods may not be sensitive enough to detect very low levels of the virus in foods yet it is generally agreed that the virus is highly infectious and that as low as ten virus particles may be sufficient to cause illness. Controls could not be put in place until we develop a greater understanding of the properties of norovirus particles.

The ability to differentiate infectious virus particles from and non-infectious ones was also discussed at length. A delegate commented that from a food industry perspective it is not only important to have a method which detects norovirus in foods but, more importantly, whether the virus particle detected is infectious or not as this has significance in terms of the safety of the food analysed. Norovirus detection methods need to include this. In contrast, whilst it was acknowledged that determining infectivity was the main limitation of the current methodologies, one delegate felt that it was not always important and that it depended on the purpose for performing the analysis. It was suggested that if norovirus is detected in a food, to some extent it doesn’t matter if the norovirus detected is infectious or not; presence of the virus (and therefore faecal contamination) alone clearly demonstrates a lack of full compliance with good hygiene practices at some stage of the food supply chain. If good hygiene practices were in place, and correctly followed, norovirus would not be detected. Furthermore, the virus picked up in the analysis may not be infectious, but there could be viral contamination more widely distributed in that batch of food which is infectious.

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5 [http://prisma-statement.org/index.htm](http://prisma-statement.org/index.htm)
Another delegate recognised that whilst we didn’t have an infectivity assay developed which can work in conjunction with PCR detection; there is a need to determine the relationship between levels detected in food by PCR using the current methods and their significance in terms of risks to human health. One way to do this was to test samples of shellfish that had definitely been linked with outbreaks and/or clusters of illness and compare these results with background levels in other food types.

A delegate felt that using RT-qPCR was not an ideal methodology for detection of low levels of RNA. PCR primers are targeted at very small fragments of the genome; the RNA detected could be in a complex with protein, it could be naked RNA, or it could be associated with an intact virus particle. It is impossible to know what state virus particles in the environment are in. Whilst PCR is a reliable detection method for norovirus in live bivalve molluscs (LBM) as it is known that LBM concentrate contamination in their digestive tract, contamination can be diffuse in other foods and harder to detect. There was a suggestion that it would be dangerous to start condemning food based on one PCR result as norovirus detected may not be viable. Another delegate felt the time had come to move away from PCR and a greater investment in whole genome sequencing was required. This would allow the detection of all the virus populations within a sample. Even though RT-PCR only identified very short regions of the genome, another delegate indicated that in research laboratories they often went on to “near whole genome sequence type” analysis.

It was put forward that any action taken on the presence of norovirus in food in future should be based on quantitation, i.e. establishing an acceptable level or limit rather than presence or absence, as this would be a more proportionate approach. A shellfish industry representative concurred and suggested that there is a need to establish some sort of limit as soon as possible as this would give industry information which can help them to make management decisions such as whether to harvest or not. Developing specialised techniques to determine infectivity will inevitably take time; in the meantime shellfish harvesters do not know what action to take.

On the issue of drug development, one delegate thought that if a drug to prevent virus replication were developed, this could be given to food handlers or patients to prevent further spread of the virus. Active drug development was taking place for clinical purposes but it was not known whether this would be useful in affecting transmissibility. The development of a drug which could be given to food handlers was generally unpopular as it raised a number of ethical issues and could introduce complacency in food handling techniques which could then lead to the introduction of other pathogens unrelated to norovirus.
Norovirus methodology: Summary of research gaps identified*

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<td>● More investment in whole genome sequencing for the characterisation of norovirus and other foodborne viruses</td>
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<td>● Surveillance to generate more information about levels of norovirus occurring in food in the UK</td>
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<td>● Further research to improve our knowledge of norovirus diversity</td>
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<td>● Development of a combined genomic and capsid integrity assay to distinguish between infective and non-infective norovirus particles</td>
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<td>● Refinements to current RT-PCR to improve detection of low numbers of norovirus particles in all food matrices</td>
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<td>● Develop new norovirus detection methods to allow detection of low number of virus particles</td>
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<td>● Further research to improve our understanding of norovirus binding properties and possible methods of inactivation</td>
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* List not in order of priority

NOROVIRUS IN THE FOOD CHAIN

Norovirus in the food chain: Catering and food handlers

Viruses in catering environments
Professor Lisa Ackerley, Hygiene Audit Systems Ltd and Salford University

Lisa Ackerley described a two-pronged action plan involving preventive and reactive measures to deal with issues of viruses in food premises. As a mode of prevention, all businesses are required to have a documented food safety management system (FSMS) based on Hazard Analysis and Critical Control Point (HACCP)\(^6\) principles. Hazards should be identified in the purchasing step, thus establishing a critical control point. However, further down the food chain, controls such as prevention of cross-contamination could reduce risks of viruses spreading from contaminated food to other foods.

It is essential that when an incident takes place, staff know what to do and the business reacts rapidly in a planned manner. This can be very helpful in containing the spread. Furthermore, it is important that staff receive not just level 2 food safety training, but also trained to follow food safety management system, know how to take action and know where to get help.

Appropriate disinfection techniques need to be employed and should be fit for the surface they are applied to and businesses may benefit from having a decontamination team that deal specifically with an incident. To effectively decontaminate uniforms for example, should guidelines be introduced requiring that businesses launder clothes professionally? Some businesses expect workers to wash their uniforms at home and this could introduce viruses to the catering environment.

\(^6\) [http://www.fda.gov/Food/FoodSafety/HazardAnalysisCriticalControlPointsHACCP/default.htm](http://www.fda.gov/Food/FoodSafety/HazardAnalysisCriticalControlPointsHACCP/default.htm)
Uniforms needed to be laundered at 90°C which was unlikely to be achieved in a domestic setting.

In addition, though food safety management system state, in accordance with Fitness to Work Guidelines that staff should not return to work until they have been symptom-free for 48 hours, there is little incentive to do so as they could potentially lose earnings. Given the low wage of catering staff and many of which work on a short contract basis, this means that people may return to work early to avoid loss of pay.

Overall, it was acknowledged that whenever staff return to work, they could still be carrying the virus asymptomatically, and therefore hand washing after using the toilet is essential. Previous legislation required “Now Wash Your Hands” notices in toilets, and it may not be a bad thing to return to this.

The food handler’s role in norovirus outbreaks experiences from Gothenburg
Ms Nancy Nenonen, University of Gothenburg

A presentation by Nancy Nenonen described the molecular epidemiology and laboratory perspectives of two outbreaks where norovirus infection was traced to consumption of a given food, and thereby to a specific sick food handler.

In the first of these, a widespread confectionary outbreak, gastro-enteric symptoms in approximately 300 patients were linked to consumption of cakes from a confectionary shop. The head baker described having had a “flu-like” illness with fever, diarrhoea and vomiting 14 days before the outbreak was recognised in February 2004, at the height of the “winter vomiting disease” season. He had returned early to work, as there were large orders to be prepared before Easter. In particular one business firm had ordered marzipan cakes to be distributed as a complimentary gift to their clients across the city. Norovirus genotype II strains were detected in samples from baker and patients, and secondary spread was noted. Inspection of the bakery revealed poor standards of hygiene and the bakery was closed for cleaning.

A recombinant norovirus GIIb/II.3 capsid strain was identified in 7 of 9 patient samples received for laboratory analysis. Norovirus strains detected in patient samples showed high nucleotide similarity (100%) to the strain found in the baker’s faeces. This NoV recombinant strain was first recognised across Europe in 2000 being particularly infectious for children. This was one of the earliest experiences of a large outbreak where genetic analysis of the virus strains detected was used to determine the point source of infections.

However, strains of norovirus genogroup I and II, and sapovirus, can be implicated in community outbreaks throughout the year, as experienced in a more recent hospital restaurant outbreak from September 2012. Preliminary investigations of this non-seasonal outbreak, based on laboratory investigation and a questionnaire survey, indicated the point source of infection as fresh raw carrots. These had been prepared by a food handler who had just recovered from a short bout of diarrhoea and vomiting 3 days before. Norovirus genotype I strains were implicated in this outbreak.
With adequate outbreak sampling of food handlers and patients, foods and environment, phylogenetic studies based on viral sequencing can strengthen the epidemiological evidence of a food borne outbreak linked to a recently sick food handler. Unfortunately, despite awareness of the problems associated with food borne transmission and attempts to improve hygiene standards in the catering environment, such outbreaks do recur regularly. However, molecular epidemiology performed on samples from food handler, food and patients can help clarify these foodborne norovirus outbreaks, as described in experiences from western Sweden.

**Interactive discussion - Norovirus in the food chain: Catering and food handlers**

Delegates were asked to consider the following questions:

a) What are the barriers to solving this issue?

b) What intervention/prevention measure would be effective in reducing the spread of norovirus by food handlers?

c) What do you believe are the research gaps in this area?

A delegate highlighted that the 48 hour exclusion recommended for a person infected with norovirus was based on this being a reasonable amount of time to assume that loose stools had stopped and that good personal hygiene was achievable by infected individuals. However, it should not be assumed that individuals would have stopped shedding norovirus after this period. Excluding individuals from the workplace based on their likelihood of shedding the virus was considered to be an unattainable goal.

The implementation of personal hygiene was therefore considered to be a critical measure for controlling transmission from food handlers. It was suggested more research was needed to understand the efficacy of hand washing products and the effect of water temperature on hand washing. In addition, running water was vital to washing hands as having plugs in sinks only encouraged the survival of pathogens in the sink. However, the problem identified here was that in many catering outlets, there was no hot water temperature control and as a result people were either washing their hands in cold water or not washing their hands at all. Therefore, improved guidance for hand washing would be helpful. Another issue was that in some catering outlets people were handling money at the same time as preparing food and this was an obvious risk factor.

Following on from this, a delegate asked how do we make people wash their hands properly and what were the consequences of not doing so? What prevents people from washing their hands? For example do certain soaps/detergents cause irritation of hands and therefore individuals are less likely to use them? Anecdotal evidence provided by one delegate from their own CCTV monitoring of hand washer entrance to a food factory suggested large numbers of people either gave a cursory wash or simply walked straight through. Therefore this raised the question what if there was another way of making people wash their hands? It was suggested that more social science research was needed to understand people’s behaviour.
Another delegate highlighted a CODEX report entitled Guidelines on the application of general principles of food hygiene to the control of viruses in food\(^7\). This document focused particularly on norovirus and hepatitis A.

A delegate mentioned that although the discussions had focussed on hand washing it was equally important to determine the effectiveness of detergents in decontaminating food preparation surfaces, uniforms and soft furnishings in food environments and producing guidance on the best cleaning practices.

Some delegates felt that there were barriers to change, with the media being a considerable barrier when competing with messages such as “we are too clean for our own good”.

Finally, one delegate suggested that personal hygiene was also an issue of engineering, as he said he could not wash hands without handling taps and could not get out of restrooms without handling doors!

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Norovirus in the food chain: Catering and food handlers - Summary of research gaps identified*

- Research on the effectiveness of hand washing procedures, agents used and water temperatures in removing norovirus
- Research on the efficacy of disinfectants on different surfaces such as food preparation surfaces, uniforms, kitchen equipment and soft furnishings.
- Lack of knowledge of how food is contaminated through the food chain. For example to what extent do food handlers contaminate food versus becoming contaminated by food?
- More surveillance required to understand environmental contamination in food environments
- A cost/benefit analysis of introducing statutory sick pay from day one versus the cost of norovirus infection
- Sentinel surveillance to detect and improve outbreak investigations
- Research to understand the length of time infected individuals shed norovirus post symptomatically and how this can be used to inform safe periods to return to work
- Research to determine the extent of asymptomatic shedding in the community/food handlers

* List not in order of priority

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\(^7\) [www.codexalimentarius.org/input/download/standards/13215/CXG_079e.pdf](www.codexalimentarius.org/input/download/standards/13215/CXG_079e.pdf)
Norovirus in the foodchain: Fresh produce, shellfish and sewage discharge

Norovirus in fresh produce
Dr Nigel Cook, Food and Environment Research Agency (FERA)

Nigel Cook gave a presentation on norovirus in fresh produce. Although no large outbreaks attributed to fresh produce had yet been reported in the UK, there had been several outbreaks of norovirus in other countries where these food commodities were implicated. Surveys of fresh produce which had been undertaken recently in Europe and Canada found evidence of enteric viruses contaminating a small percentage of the sampled foods.

The main routes and causes of contamination in fresh produce were described as handler’s hands and sewage-contaminated irrigation water and inadequate practices during food production, processing and prior to consumption. The European Commission Framework 7-commissioned ‘Integrated monitoring and control of foodborne viruses in European food supply chains’ project (also referred to as VITAL) found more non-compliance with prerequisite food safety programmes during fresh produce production than during processing or at point-of-sale. Critical control points identified as significant for viruses were irrigation water and workers’ hands.

It was identified that prevalence of norovirus in UK fresh produce was unknown and that the prevalence of norovirus in imported fresh produce also needed to be ascertained.

Norovirus in shellfish
Dr James Lowther, Centre for Environment, Fisheries and Aquaculture Science (Cefas)

James Lowther summarised the current state of knowledge on norovirus contamination in shellfish and the link between norovirus results as determined by PCR and risks to human health. He explained that bivalve shellfish feed by filtering large quantities of water and can thus concentrate pathogens which contaminate the waters in which they grow, and that the large outbreaks that can occur as a result cause significant economic impact on producers. Oysters were the main shellfish associated in norovirus outbreaks, but mussels and clams have also been implicated. Outbreaks have occurred in Europe and other parts of the world, including New Zealand. Currently, risk assessment and management relies upon faecal indicator organisms such as E. coli which have repeatedly been demonstrated to inadequately reflect the risk from human enteric viruses.

To investigate the prevalence, distribution and levels of norovirus titre in oyster harvesting areas in the UK, the FSA funded a two year study (project FS235003) carried out at Cefas to establish a baseline for norovirus in UK oysters. The study established baseline data for prevalence, levels, seasonality and correlation with risk factors. Levels were found to be considerably higher in the winter and early spring.

Whilst PCR tests only detect the genetic material of norovirus, and therefore provide no direct information on infectivity, some recent research has demonstrated a
relationship between quantities as determined by PCR and health risks. Higher levels by PCR appear to carry higher risk, however this finding was based on a limited dataset of oyster samples directly linked to illness. Research is ongoing to establish links between human health risks and different levels of norovirus RNA.


**Sewage discharges and norovirus in the environment**

Ms Elaine Connolly, Department for Environment, Food and Rural Affairs (Defra)

Elaine Connolly showed a map of England’s shellfish waters many of which coincide with large areas of the human population. Whilst there were many potential pollution sources including agricultural sources, dogs and birds, waste water from households, commercial premises and public institutions was the main source for norovirus infection in the community to enter the coastal and estuarine environment. Sewage can go through various stages: the preliminary stage to remove large objects, secondary treatment in a tank and possibly a tertiary stage involving UV treatment.

In an initial small study, it was shown, that conventional sewage treatment processes have the potential to reduce the overall levels of norovirus contained in sewage. However, it was stated that only a minority of plants which directly impact shellfish or bathing waters in the UK have a tertiary treatment stage, which is most commonly UV disinfection. In addition, various inland discharges all feed in to the eventual coastal discharge as viruses are very robust and not thought to be significantly degraded in the environment. Currently, several challenges have been identified as key such as the understanding of environmental persistence and dispersion of norovirus and environmental reservoirs. There is no known method to remove norovirus from waste water, and the only alternative is to remove all discharges from catchments which contain shellfish waters. This would be a hugely expensive undertaking. Defra are working with Cefas to gather evidence to develop an effective and proportional policy response to addressing concerns about norovirus levels in shellfish.

**Interactive discussion - Norovirus in the food chain: Fresh produce, shellfish and sewage discharge**

During this interactive discussion session, delegates were asked to consider the following questions:

- a) What are the barriers to solving this issue?
- b) What intervention/prevention measure would be effective reducing norovirus in fresh produce/shellfish?
- c) What do you believe are the research gaps in this area?

Delegates expressed concerns that storm water overflows and Combined Sewer Overflows (CSO) have potential to cause significant norovirus contamination of the environment and food such as live bivalve molluscs. It was suggested that with the
changing weather patterns (i.e. flooding) in recent years; this situation could get worse. However, it was thought that to prevent CSOs and such events, there would be a need for vast storm water overflow tanks, which are impractical and expensive. It was felt more work was needed to reduce contamination found in discharges from sewage treatment works.

If contamination can be removed at the source, in this case in sewage, the shellfish industry would not have a problem and it was suggested that this ought to be the primary focus for action. It was acknowledged that multi million pound investments would be needed from water companies to reduce norovirus contamination in effluent from sewage treatment works and that these costs would have to be passed onto consumers. It would be difficult to justify such as huge investment given the relatively small size of the UK shellfish industry and the likely significant increases in water bills, especially given the current economic situation. It was suggested that consumers are unlikely to be prepared to pay more for their water services; therefore there is a need to find other solutions.

A comment was made by a delegate that people often swim in areas of water potentially contaminated with norovirus so it is not only the shellfish consumers who would benefit from improving the quality of water discharges/effluents.

One delegate felt that the opportunity for industry to participate in schemes to develop new sewage management processes is now more limited due to the loss of schemes such as the Defra-LINK (food manufacturing research) scheme - this should be restored to aid this process.

Other delegates felt that there was a need to consider the cost/benefit ratio in terms of further improvements to current water treatments. Given that the costs of these improvements are likely to be high, there was a need to estimate the costs of foodborne illness associated with the consumption of shellfish. This would allow comparisons between the two to be made and determine whether there would be any cost savings in changing our sewage system. Another delegate suggested that it is more difficult to calculate the cost of one shellfish related case as we are dealing with a complex inter-related system where secondary transmission is common. For example a person who has acquired norovirus from consuming contaminated oysters is highly likely to spread the virus to others which makes it difficult to ascertain the total cost.

There was agreement that more data on infectious dose by looking at viral load in outbreak associated foods would be useful; data only exists from a small number of outbreaks, compared to the number of suspected foodborne norovirus incidents reported to the UK competent authorities. However it was recognised that it is often not possible to obtain samples from batches of food associated with outbreaks as the batch has often already been consumed by the time notifications of illness are received.

Delegates felt that the standard protocol for depuration or sanitization of the sea water used in the depuration process had existed since 1995 and that this needed to be re-evaluated. There was a need to find innovative ways to decontaminate oysters whilst
in depuration tanks, perhaps by interfering with the mechanism by which norovirus binds to the animal structure.

In commodities other than shellfish, there exists the same need to better understand the limit of norovirus below which there is a reduced risk to public health. This would facilitate establishing a limit in other relevant food to prevent the most contaminated products from reaching the market. It was emphasised that it is important to prevent contaminated food coming from elsewhere such as imported fresh produce which could introduce different genotypes in to the community and may increase the chances of large outbreaks. The need to focus on the prevention and control of norovirus already circulating in the UK community was also highlighted; this would need wider involvement from other Departments, Agencies and funders to collaborate with FSA.

Norovirus in the food chain: Fresh produce, shellfish and waste water treatment discharges - Summary of research gaps identified*

- Additional food surveillance to provide data on the UK prevalence data of norovirus in fresh produce at retail
- Research to assess the effectiveness of depuration in removing norovirus from oysters and ways this process could be improved
- Investigation of alternatives to depuration in removing norovirus from oysters such as high pressure, UV, ozone, irradiation, offshore production
- Establishment of the infectious dose in different food commodities including shellfish and fresh produce (lettuce and berries)
- Research to improve detection methods to isolate norovirus from different food matrices
- Identification of processes or processing stages which present the greatest risk of contamination and identify interventions
- Development of models to estimate the impact of interventions for reducing norovirus in the foodchain on the overall incidence of human infection
- Development of cost effective methods for treating waste water to inactivate viruses

* List not in order of priority

FOODBORNE VIRUSES: INTERNATIONAL PERSPECTIVE

The USDA-NIFA food virology collaborative (NoroCORE): An integrated, multidisciplinary approach to the study and control of foodborne viruses
Professor Lee-Ann Jaykus, North Carolina State University, USA

Lee-Ann Jaykus joined via teleconference and gave an overview of the work conducted by the USDA-National Institute of Food and Agriculture Food Virology Collaborative project (NoroCORE), which was established to address the important public health issue of viral foodborne disease. In collaboration with several partners and stakeholders, the initiative’s long term goal is to reduce the burden of foodborne disease associated with viruses, particularly noroviruses. Within the long term goals the 6 core functions have been identified:
Core goal 1: Develop improved methods to facilitate the study of norovirus for example, an in vitro cultivation system, and validate alternative cultivable human norovirus surrogates

Core goal 2: Develop and validate sensitive, rapid and practical methods to detect and genotype human norovirus

Core goal 3: Collect and analyse population data on the burden of virus-associated foodborne disease

Core goal 4: Improve our understanding of the occurrence and behaviour of human norovirus in the food safety continuum with the aim of developing scientifically justifiable control measures (prevention and control)

Core goal 5: Translate and disseminate new knowledge to reach target audiences. An example provided was to publish one-page information sheets on the risks of norovirus to specific stakeholder groups; and finally

Core goal 6: Build scientific and human capacity by fostering information exchange and expand professional capacity through formal student education and training initiatives.

Throughout the presentation, examples were provided supporting the progress of each goal and the efforts made by the NoroCORE collaborative with the long-term goal of producing a measureable reduction in burden of viral disease. Some of the broad outcomes expected were practical and commercial control strategies, increased awareness of foodborne viruses; and the delivery of meaningful information to relevant audiences.

Further information on the USDA-National Institute of Food and Agriculture Food Virology Collaborative (NoroCORE) is available at http://norocore.ncsu.edu/

**Foodborne viruses: A European Food Safety Authority (EFSA) perspective on methods, limits and control options**

Dr Ernesto Liebana, European Food Safety Authority (EFSA)

Ernesto Liebana described some of the work conducted by EFSA on methods, limits and control options available to tackle the issue of foodborne viruses. Viruses were responsible for 50% of outbreaks caused by fruit and vegetables in the EU in 2010. In outbreaks caused by crustaceans, shellfish molluscs and products thereof, in the EU in 2010, calicivirus was identified in approximately 36% of cases. However, at the EU-level it was unknown how much viral disease could be attributed to foodborne spread. The relative contribution of different sources to foodborne illness has not been determined.

In the EU, the major route of transmission for norovirus is person-to-person. However, food may become contaminated by norovirus during all stages of the food supply chain (production-processing-handling). Studies in some European Member States
suggested that the amount of norovirus disease attributed to foodborne spread may be significant. The transmission routes as described in several earlier talks are numerous and inter-related and EFSA recommended focusing controls on preventative measures to avoid viral contamination rather than trying to remove or inactivate viruses in food. Primarily, this intervention could be targeted at pre-harvest for some products, although at harvest and post-harvest phases it may be suitable for other products. In addition, the training of food handlers about hygiene requirements and specific viral contamination of foods and food preparation environments was recommended to reduce the risk of contamination of ready-to-eat foods.

EFSA also recommend the establishment of microbiological criteria for viruses. Micro-criteria for norovirus are useful for validation of HACCP-based processes and procedures and can be used by authorities as an additional control to improve risk management in production areas, during processing and retail. Whilst there is no threshold infectivity limit for norovirus detected by PCR, the probability of becoming infected increases with the dose. Nevertheless, harmonization and standardisation of PCR-based detection is on-going to establish criteria for pathogenic viruses in live bivalve molluscs when the analytical methods are developed sufficiently.

With the existence of quantitative data on viral load, EFSA recommends that risk managers consider establishing an acceptable limit for norovirus in oysters to be harvested and placed on the market.

**Molecular epidemiological surveillance of foodborne viruses in an international context**
Professor Marion Koopmans, National Institute of Public Health and the Environment (RIVM), The Netherlands

Marion Koopmans gave a summary of Noronet, an initiative aimed at providing a platform for rapid exchange of information and data on norovirus cases and outbreaks, to map the norovirus diversity internationally and to use this information to inform public health action. Participants share information, get periodic reports and email alerts about new variants. One of aims is to standardise the nomenclature for norovirus genotypes in order to compare data from different countries. A typing tool is available on the website www.noronet.nl.

A common database with information on more than 10,000 outbreaks, including some outside Europe, with matching strain sequences has provided insight on virus diversity observed in outbreaks in healthcare settings, the evolution of prevalent norovirus genotypes and the potential use of molecular typing to identify common source outbreaks.

**Interactive discussion - International perspective on foodborne viruses**

During the interactive discussion following on from the international perspective presentations, delegates were asked to consider the following question:

a) Is there any research that you have heard that would be effective in tacking this problem in the UK?
The need to develop a cell culture system for the propagation of norovirus was noted. It was recognised by delegates that there was already a significant investment by the noroCORE initiative and wished them success as this breakthrough would be very useful.

In addition to a viable cell culture system, another delegate suggested a need for research into the usefulness of surrogates, particularly their ability to represent the behaviour of human norovirus in the absence of methods to culture human norovirus.

From a US perspective, the highest priority in the NoroCORE programme is to develop a propagation system for human norovirus. A large amount of research to develop a system for achieving this has been carried out over the last 40 years with limited success, which highlights the difficulty of the task.

Another delegate commented that the FSA needs to revisit the advised time and temperature conditions for cooking shellfish. Current advice, which was established many years ago, recommends cooking shellfish at 90°C for 90 seconds whereas today shellfish are often cooked or seared to milder temperatures. Therefore it was considered useful to re-evaluate what would be an effective process so we could prioritise the risk in terms of which shellfish were obtained from which waters.

A delegate commented that there was very little data on norovirus prevalence and levels in fresh produce (lettuce and berries) in the UK. It was noted that future surveys of fresh produce should capture data on what standards were in place, did they comply with global good agricultural practice, were they ready to eat produce, country of origin, etc as this would be very useful.

It was noted that good data existed on outbreaks in hospital settings and that work was also conducted by the virus reference departments but there is a need for better linkage between those investigating hospital outbreaks and cases reported in the community. Currently, when pandemic strains emerged we do not know what effect they are having on outbreaks. It was suggested that systems were still based around detection by electron microscopy, where a few samples were taken from patients when they first became ill. If norovirus was detected in 1 or 2 samples, it was usually assumed as norovirus and no more sampling from outbreaks in hospitals was conducted. However, when several wards had to close the question was asked if it was one outbreak or several. This couldn’t be answered unless more thorough and systematic sampling and typing was conducted.

Delegates had contrasting opinions on the usefulness of detecting antibodies to norovirus in food handlers. One delegate suggested that if an antigen test could be developed, it would provide a rapid approach to screen food handlers and determine whether they were carriers or not. However, another delegate found this approach impractical as they questioned how often food handlers would be screened hourly/daily/weekly/monthly? A better way to protect against an infected food handler was scrupulous personal hygiene. Countering that, another delegate could see tests application of antigen in assessing the extent of infection during an outbreak. In the case of an outbreak, many people may be unaware that they have an infection if they are post symptomatic or asymptomatic. If there was a way of seeing who was
shedding during an outbreak it would have added value. However, again it was noted that whilst this was a useful method for documenting outbreaks and a very useful research method, it was not a method for control or prevention.

Delegates also discussed the need to think of more global networks, not just Europe and North America, as recent evidence suggested that norovirus was a global phenomenon. What we were seeing this year was almost certainly a pandemic and therefore we should be doing what the influenza community do. If we ever got to the point of introducing vaccines for norovirus, particularly for vulnerable people, it was absolutely essential we had global surveillance of norovirus diversity particularly in the Far East and China. Now was the time to think about global surveillance and how we could integrate it into national and continental surveillance.

The need for scrupulous personal hygiene was also identified as the most important message to instil in food handlers as well as the general population and further work was needed to understand why food handlers and the general population might not adhere to this. Social science based research was suggested as a means of understanding what motivates or de-motivates food handlers to observe appropriate hygiene and furthermore how messages should be communicated to them to ensure that they are put in to practice and therefore protect the food chain.

Another delegate mentioned the importance of gaining a better understanding of asymptomatic shedding in the community, as this could be the basis for social pressure needed to change personal hygiene behaviours. In a hospital setting, it was suggested that this could be used to identify staff that were or were not infectious and/or still shedding; there was currently an assumption that people who were not symptomatic were not shedding. Data to inform about the level of shedding by asymptomatic people was lacking and control was always predicated on symptoms and wellness. However, another delegate suggested that the reason for keeping people off work or from school when they were ill was not because they were shedding, but because it becomes impossible to maintain personal hygiene when exhibiting norovirus symptoms such as vomiting and diarrhoea. Although 48 hours after cessation of symptoms, food handlers may still be shedding, at this stage they are able to observe correct personal hygiene which will prevent contamination of the food. We needed to get the point across that everyone could potentially be a shedder (i.e. either post-symptomatic or asymptomatic) and all of us were responsible so we all needed to wash our hands. People could be shedding up to 25 days post-asymptomatically and we don’t have an idea of what proportion of the healthy population was actually carrying norovirus whilst completely asymptomatic.

The biggest hand hygiene issue in the US was poor compliance in retail settings, with only 10-15% of food handlers washing their hands. It was suggested that this was due to the strict hygiene rules in place that were not realistic for busy catering or retail establishments. Therefore a more risk-based approach was necessary such as reinforcing the message that it was more important to wash hands after using the restroom than after touching the face.

More research was needed to assess whether toilets and restrooms were environmental reservoirs for human norovirus and whether this was a means by which people were getting infected. Additionally, it was worth considering whether food
handlers should have separate restroom facilities from the general public. Finally, it was worth considering the contribution of norovirus spread by vomiting in viral outbreaks not only in food settings but also general person-to-person spread.

Foodborne viruses: International perspective - Summary of research gaps identified*

- Research to develop a method to culture norovirus
- Application of next generation sequencing techniques to detect foodborne norovirus
- Identification and agreement on internationally suitable surrogates for norovirus
- The co-ordination of international collaboration to avoid duplication of research efforts
- Further surveillance to determine the prevalence and levels of norovirus in different food commodities such as fresh produce and shellfish
- Integration between epidemiological and virological investigation in outbreaks
- Development of vaccines similar to work being done with influenza
- Dose-response studies to determine infectious dose and inform on limits

* List not in order of priority

Interactive session - Analysing and prioritising norovirus research areas identified

Delegates were divided into groups and asked to consider a list of norovirus research areas identified during the conference discussions and to prioritise the key gaps which needed to be addressed.

Surveillance

A need was identified for good systematic surveillance and incorporation of next generation sequencing with associated computing and bioinformatics support. This approach would provide the ability to detect and characterise norovirus in one step. Furthermore, it would increase the sensitivity to detect multiple infections and identify unusual and emerging strains. It was felt that PCR had probably reached its limit of sensitivity and it can only detect what the researcher looked for.

It was important to achieve integration between epidemiological and virological investigations in outbreaks. This was practically achievable in the next few years. Molecular trace-back of international outbreaks was also important as this would improve our understanding about what was happening internationally and domestically. It was recognised that without good surveillance we could not understand the contribution of the food chain to the overall epidemiology of norovirus.
In addition it was questioned how much the respiratory route of transmission contributed.

Infection and immunity

On the issue of surrogate indicators of contamination, delegates felt that an agreement on cheap and easily cultivatable surrogates for norovirus was required. This could provide biological information that the food industry needed to evaluate interventions and could also be applied internationally like those already in place for *E. coli* and could also be applied to disease investigations where food could be contaminated. Molecular methods are not always practical for evaluating the success of interventions because they typically detect genetic material, which may still be present even if pathogens have been inactivated or destroyed.

To develop a risk-based strategy for norovirus and implement levels of acceptability, it was important to understand the norovirus dose-response relationship. Therefore it was important to understand the relationship between the amount of norovirus present in food and the risk that presents to human health. Furthermore, this could be extended to specific food types, for example, determine a practical risk-based upper limit in relevant ready to eat foods.

Information was lacking on human immunity to norovirus and it was felt such knowledge was crucial to understanding the risk of secondary (recurrent) infections. We do not have a good test for immunity and it was felt worthwhile to expend further effort studying acquired and innate immunity and whether immunity changes during the course of epidemics. This could then be used to better model the disease in populations. In addition, delegates felt there needed to be a better understanding of what asymptomatic carriage meant in terms of how long were people carriers, how heavily they shed the virus, how long did it last and what did this mean for infectivity. This could then be used to help support advice given to people and food businesses.

Delegates appreciated the importance and significant benefits a culture system for norovirus would provide:

- It would allow researchers to understand more about the virus and how it replicated and its infectivity
- It would allow for drug susceptibility studies and to determine the effects of antivirals and other disinfectants
- Possibly facilitate the development of potential vaccine candidates
- Determine the viability of norovirus - if virus detected grows, this demonstrates its viability.

Delegates felt that since US research are exploring the development of a culture system as a priority it would seem appropriate to let them lead on this area; an integration of efforts worldwide was sensible to prevent the unnecessary duplication of work.
Detection methods

There was a consensus that further research was needed to be able to distinguish between infectious and non-infectious norovirus both at the virus level and in people. This would be hugely beneficial by increasing the ability to interpret results of sampling in terms of public health implications. If there was a method to screen out non-infectious particles, it would make it possible to determine the level of infectious viruses in a food or on a surface and determine more accurately how that translated into risk for human health. To achieve this, delegates felt that the use of assays that considered both capsid and genomic integrity should be explored.

It was also suggested that the capsid proteins could be used as an alternative detection method for norovirus in food stuffs since it is much easier to concentrate proteins than viruses.

Food handlers and social sciences

Many delegates felt the need for more research and greater clarification on effective technical solutions for preventing human infections and the effectiveness of cleaning regimes. Delegates thought that the efficacy of different hand washing products and cleaning detergents for virucidal activity needed to be investigated. Furthermore, it was suggested that research into the behaviour and survival of norovirus on different surfaces might be useful; do different surfaces need to be cleaned in different ways e.g. hands, hard surfaces and soft furnishings. Therefore this would provide a basis for best practice recommendations to people in all environments such as catering/cruise liners/hotels/home environments/schools and hospitals.

It was also felt that a better understanding was needed for the variety of ways a food environment could become contaminated, be it from food handlers or from customers, hotel guests, etc. Determining the relative importance of each of these pathways would allow targeted cleaning regimes and mitigation strategies for dealing with contamination events.

Whilst investigating the research priorities, delegates came up with a number of social sciences related projects (see below) that could be considered.
List of social science related questions identified by the delegates

<table>
<thead>
<tr>
<th>Social science related questions*</th>
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<tbody>
<tr>
<td>Why don’t people wash or want to wash their hands?</td>
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<tr>
<td>Do food handlers understand the purpose of hand washing and what they need to achieve by washing hands?</td>
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<tr>
<td>What are the barriers preventing people including food handlers from washing their hands?</td>
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<tr>
<td>How could we improve compliance and what were the best strategies for raising awareness and changing behaviours?</td>
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<tr>
<td>What would make people change their minds and attitudes?</td>
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<tr>
<td>How could we persuade all food handlers that thorough and effective hand washing is a vital part of good hygiene practice in catering environment?</td>
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<tr>
<td>Could public awareness campaigns be used to improve public knowledge of risks posed by norovirus and how they can be mitigated, similarly to those that have been run previously for influenza?</td>
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* List not in order of priority

Delegates felt that making sure there was a good understanding of the risk of norovirus and of infection control methods was a priority. This needed to be ingrained in food safety culture regardless of the size and nature of the business. It was important that these messages were more effectively communicated and that social media had a role to play in the delivery of these messages. It was recommended that the FSA needs to fund a research study to determine the current proportion of people who do not practice effective hand washing.

Shellfish

Whilst some delegates felt it was worth investigating the possibility of alternative site selection for production of oysters, away from major sources of contamination, others felt it better to focus on post-harvest treatments as it was unlikely to be possible to change the occurrence of shellfish production in large-scale viral pollution zones. Such post-harvest treatments considered were to concentrate on improving depuration and investigate innovative or alternative methods of improving the ability to remove or displace the norovirus from oysters. This would require investigating the properties of the virus and then consider how to displace the virus from the digestive tract of bivalve molluscs.

Fresh Produce

Some delegates were not convinced how high a risk fresh produce posed for the transmission of human norovirus in the UK. Therefore it is important to determine the extent of the problem: what is the prevalence of human norovirus and other enteric viruses in fresh produce at the point-of-sale in the UK? If there is a problem it is important to pinpoint practices associated with the risk and link risks to health impacts. In addition delegates felt that it was beneficial to look more specifically at primary production and harvesting practices amongst UK produce growers to determine their
effectiveness to prevent viral contamination and determine whether they were fully in compliance with international good agricultural practices.

There was felt to be a need to understand and rank the most important interventions on a global scale. It was not clear which of these was a more effective method of controlling norovirus. We had to consider differences between the United States and Europe and which of these could be converted into best practice and lead to better interventions. We had to consider the differences in how fresh produce was produced and how shellfish were regulated.

**Key norovirus research gaps identified**

Following on from the norovirus interactive discussions held on day 1 and 2 of the conference, the research gaps identified are summarised in the tables below. The research gaps have been grouped into five board research themes (surveillance; infection and immunity; detection methods; food handlers and social science; shellfish and fresh produce) and listed. Please note that the research gaps are not listed in order of priority or importance.

<table>
<thead>
<tr>
<th>1. Surveillance*</th>
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<tbody>
<tr>
<td>i) Determine prevalence of human norovirus (enteric viruses) in fresh produce at point of sale in the UK</td>
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<tr>
<td>ii) Research to investigate the prevalence, levels and distribution of norovirus contamination in food handling environments</td>
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<tr>
<td>iii) Understand the burden of norovirus which is foodborne and determine whether food is primary source and/or contributory vehicle in transmission</td>
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<tr>
<td>iv) Surveillance to establish the extent of norovirus contamination in fresh produce and pinpoint sectors and practices associated with risk</td>
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<tr>
<td>v) Integrating packages of work molecular trace back and food chain information to try and tackle problems at source</td>
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<tr>
<td>vi) Integration between epidemiological and virological investigations in outbreaks</td>
</tr>
<tr>
<td>vii) Proper surveillance, investigations and sharing of data internationally</td>
</tr>
</tbody>
</table>

* List not in order of priority
2. Infection and Immunity*

| i) | Determine the infectious dose in different foods |
| ii) | Research technical solutions to damp down levels of human infection (disinfectants antiviral treatments, vaccines) |
| iii) | Develop a better understanding of asymptomatic carriage and shedding of norovirus |
| iv) | Better understanding of dose response relationship in humans and a need for International agreement on dose response |
| v) | Identify how norovirus survives in different food matrices and in different stages of the food chain i.e. at harvest, processing, retail and catering environments |

* List not in order of priority

3. Detection Methods*

| i) | Determine reliability of current surrogates and indicators for norovirus in different foods |
| ii) | Achieve international consensus on an appropriate surrogate for norovirus |
| iii) | More investment in whole genome sequencing for use in detection and characterisation or norovirus in one step |
| iv) | Develop a combined genomic and capsid integrity assays i.e. methods other than PCR to assess the infectivity of norovirus particles detected |
| v) | Development of a capsid detection assay and binding of norovirus thus ligand identification |
| vi) | Develop a culture system for norovirus, so more can be understood about the organism such as replication and infectivity |
| vii) | Develop methods to detect immunity (infectivity) that are applicable outside the laboratory |
| viii) | Production of reference material as a standard. Establish common repositories of strains, standardise PCR |

* List not in order of priority
HEPATITIS VIRUSES IN THE FOOD CHAIN

Understanding hepatitis E virus
Professor Dilys Morgan, Health Protection Agency

Dilys Morgan started by providing an overview of hepatitis E infection which is usually mild to moderate in severity and has an incubation period on average of 40 days. Hepatitis E was once thought to be only associated with travel as it was endemic in less developed countries, and responsible for more than 50% of acute viral hepatitis. However, in 2004 it was reported that of the 186 cases of hepatitis E in England and Wales confirmed by the HPA Reference laboratory, 17 were indigenously acquired. The infection was detected in older males and they were all infected with the genotype 3 virus. This virus was very similar to that found in pigs, supporting the concept of a zoonosis.
In 2005, 33 non-travel related infections were confirmed of which 32 had Caucasian names and a further 67 were estimated to be indigenous infections. The median age of this group was 65 years and 83% were male. When investigating the risk factors using a detailed questionnaire, similar trends appeared with people being British, older male, not eating “foreign food” or engaging in a lifestyle that could be perceived as being “risky”.

Sero-epidemiological studies of the general population in England found the seroprevalence rates increased with age, peaking at approximately 25% in those aged 50 years or over. It was therefore assumed that the majority of hepatitis E infections had to be asymptomatic. Confirmation of asymptomatic infection was seen on a cruise liner outbreak where investigations found that only 11 of the 33 passengers with acute hepatitis E were symptomatic. Even though over half of all passengers were female, 76% of those with acute infection were male.

Since 2010, there have been an increasing number of reports of hepatitis E virus infection in England and Wales, mainly accounted for by an increase in indigenously acquired cases. A case-controlled study found an association between hepatitis E infection and the consumption of pork pies and the consumption of ham and sausage. Although sausages had previously been found to be contaminated with hepatitis E virus, the study also raised concerns about other processed pork products and whether current practice was sufficient to prevent transmission of hepatitis E virus. However, several questions regarding disease manifestation and risk factors for infection remain unanswered.

Hepatitis E in the pork food chain
Dr Francesca Martelli, Animal Health and Veterinary Laboratories Agency (AHVLA)

Francesca Martelli described the situation of hepatitis E virus in the pork food chain. A case-control study investigating the consumption of raw pork liver sausage (figatellu) in France found acute or recent hepatitis E virus infection in 7 out of 13 individuals who ate raw figatellu. In addition, consumption of raw or undercooked pork meat or pork sausage 2 months prior to symptom onset was the likely cause of the 14 out of 21 cases in Germany.

As part of the European FP7 project VITAL, hepatitis E contamination levels were investigated in the pork food chain in England. The food chain was sampled at 3 different points, production, processing and point of sale. Results from this sampling, using standardised (real-time PCR) protocols detected hepatitis E virus RNA (9.5% of the raw sausages tested positive for hepatitis E virus detection) at each point in the chain including on the hand in the slaughterhouse, on a hook in the processing/cutting point and on knives and slicer at the point of sale.

It was noted in summary that whilst hepatitis E virus detection along the pork supply chain raised public health concerns, cooking meat had been demonstrated to inactivate hepatitis E virus.
Hepatitis A virus in the foodchain
Professor Marion Koopmans, National Institute of Public Health and the Environment (RIVM), The Netherlands

In the last of the conference presentations, Marion Koopmans described hepatitis A in the foodchain. Hepatitis A shares some characteristics similar to norovirus. However, unlike norovirus, hepatitis A infection has a long incubation period, limited diversity, low endemicity and results in life-long immunity. A key route of virus transmission is through faecally contaminated food or water. It used to be a common childhood infection, rendering the majority of the population immune to repeat infections. However, with improving socio-economic conditions, sanitation and hygiene, the age of first infection was increasing resulting in more illness per case because clinical impact increased with age of infection.

In more developed parts of the world, the majority of hepatitis A cases were either travel-associated or restricted to specific risk groups. However, the potential for food- or waterborne hepatitis A outbreaks was increasing. A major obstacle in detecting foodborne outbreaks of hepatitis A virus was the long incubation period. As a result, taking food histories was not very reliable and food sources were rarely considered unless cases were linked to a common food establishment or event. However, molecular typing could provide additional support for an outbreak investigation. Hepatitis A virus strains can be distinguished. Viruses recovered from different locations often represent different strains, whereas viruses from individuals in the same outbreak usually represent the same strain. Using this approach, surveillance of hepatitis A virus in The Netherlands identified infection in 42 persons and attributed 22 of these to a foodborne source.

Sequence data from viruses were shared and compared to identify similar clusters of hepatitis A virus and a match was established with an outbreak in Australia. A single sequence was present and the consumption of semi-dried tomatoes was identified as a risk factor. Similar cases were also reported in France and the UK. International sharing of data is thus an important prerequisite for feasibility of molecular cluster detection.

Panel Q&A session on hepatitis viruses

A delegate highlighted that hepatitis E is not routinely tested for in many acute hepatitis cases in the UK which makes assessing the burden of hepatitis E problematic. The delegate asked what percentage of cases was tested for hepatitis E in the UK. The panel were unable to provide the proportion for the number of cases in the UK tested for hepatitis E. The Health Protection Agency has tried to raise awareness of hepatitis E through sending out letters, adding the hepatitis E virus to laboratories Standard Operating Procedures (SOPs) and request forms. These activities did cause a temporary increase in reporting of hepatitis E cases in 2005.

In terms of the prevalence of hepatitis E virus in sausages, a delegate asked whether there was any difference in the production procedure or ingredients used in the sausages produced in the UK compared to other countries. A panel member clarified
that in the UK sourced sausages were tested, which contained pork meat, salt, pepper and a few spices, whereas in other countries such as Spain they looked at fermented sausages like chorizo which are quite different. The delegate asked whether pork liver was included as a sausage ingredient in the UK and the Panel member confirmed that liver was not a component.

A delegate asked what was the attributable burden of pork pies and sausage meat in the case control study? A panel member clarified that about 90% of cases had eaten either pork pie, ham or sausages but she did not believe it to be an exact picture. Hepatitis E virus is in the food chain and there are likely to be other sources and reasons why people acquired hepatitis E. Clarification was also sought on whether questionnaires were collected from controls subsequently turned out to be antibody positive for hepatitis E but asymptomatic? The risk factors to be antibody positive will be different from the risk factors for disease and this may provide some indication of lifetime exposure of people to hepatitis E in the UK. The panel member also confirmed that no questionnaires on antibody positive asymptomatic individuals were collected as only people who were antibody negative and eligible to be controls were tested.

A delegate commented that there is a lack of data on the thermal inactivation of norovirus in shellfish but the same applies to both hepatitis A and E viruses in food products such as meat products, sun dried and sun blushed (which go through an oven process) tomatoes. For years the food industry has been cooking foods so that the internal temperature reaches 70°C for 2 minutes but there is a need to determine whether this is effective in destroying viruses like norovirus, hepatitis A and E in different food matrices.

A delegate asked if the panel were aware of any studies that looked at the incidence of hepatitis E virus in high risk meat products such as salami and dried meats (Parma Ham or ready-to-eat chorizo) or the incidence of hepatitis E in the population in countries where these products are consumed such as Spain and Italy. The panel thought that there were not many studies but were aware of a comparative study carried out several years ago which tested people across Europe. This study did not find any difference in prevalence of hepatitis E between products and regions but did find strain differences. You may see some variations in incidence due to production differences between regions, for example butchers which use traditional family sausage recipes. A delegate added that hepatitis E virus is the most common cause of enteric hepatitis in the UK and more common than hepatitis A.

It was asked whether data is available from waste water studies to look at presence of hepatitis E virus RNA from pig farms or human waste water sources. A panel member responded that she was aware some work has been carried out in Reading. In terms of her work, some water samples were tested but hepatitis E was not detected. Samples were also collected and tested from on-farm slurry lagoons (big tanks that collects the liquid waste from the farm and then used to irrigate crops) and found hepatitis E virus in large numbers in these samples.

It was suggested that an inability to obtain potential risk exposure information on sporadic cases of hepatitis A cases which are not associated with travel is a major problem in England and Wales. In particular it is very difficult to get engagement with
the public health sections of NHS in the UK, trying to get notifications and samples. From the very small number of cases where hepatitis A capsid sequencing is carried out, that you can see clusters in diverse places in the UK suggesting that there has been importation in the UK. However researchers are unable to investigate this further as these clusters are so infrequent and in such low numbers. In endemic countries childhood exposure protects against serious illness. In the UK, we are now seeing adults who are acquiring hepatitis A for the first time in adult life that can cause severe disease. There is a real need for North West European countries to focus on the importation of food from abroad because viruses in imported foods are an emerging issue. This statement was supported by a numbers of delegates in the audience.

The facilitator thanked the panel members for their input before inviting the audience for their views or to raise questions on any of the topics which were presented on day one and two of the conference.

A delegate said it would be useful to bear in mind the difference in culture virus and how the virus behaves naturally. What is less known is how norovirus survives in vomit and if it behaves differently in different matrices (i.e. faeces, food etc). Most of the conversations over the last two days have focussed on faeces and food handlers whereas vomit was hardly discussed. Another delegate responded that a semi qualitative RT-PCR application looked at vomit and diarrhoea in parallel and only found a couple of CT differences between the two, suggesting that vomit aerosol is very important in terms of spreading norovirus.

A delegate reminded the audience that there is often a problem with basic sanitation practices in countries from where foods are imported into the UK. The difficulty for the FSA is that this is not under their jurisdiction. It was important for importers to look at hygiene on production sites. Due to increasing globalisation, this is a major problem within Europe and the countries it trades with. It’s a very important problem that is getting worse and the issue is how we tackle this.

**Closing remarks**
Mr Alisdair Wotherspoon, Food Standards Agency

Alisdair Wotherspoon, Head of Science Delivery, brought the conference to a close by thanking speakers, delegates and table facilitators for their time and expertise. The discussions held at this conference identified a number of research areas, both fundamental and practical in nature, which would be considered further by the FSA. It was highlighted that next generation sequencing could play an important part in addressing some of these areas, and that the FSA was involved in an international initiative in this area which would be important for the future.

Norovirus is very complex in terms of its biology and there are barriers to identifying effective interventions that might help reduce the incidence of foodborne norovirus. Furthermore, there were other important routes of transmission to consider other than food, most notably person-to-person spread, so it was essential that the issue of foodborne norovirus was not viewed in isolation from other sources and a joined up approach to tackling norovirus should be adopted. He emphasised the need to reflect
on the discussions held and the FSA would seek views from its Advisory Committee on the Microbiological Safety of Food (ACMSF). In addition, the FSA intended to discuss with key partners, including other government departments/agencies and research councils, how we could tackle some of the important issues raised over the last two days. It was also important to take on board other existing and ongoing activities in the area of foodborne viruses to avoid duplication.

Finally, Alisdair thanked Keiron White, The Live Group and the FSA team (Kara Thomas, Bobby Kainth, Dev Churamani, Adela Wegrzynski, Nick Laverty, Paul Cook and Bob Martin) for organising a very successful event.

Copies of the presentations given at this conference can be found at: http://www.foodbase.org.uk/results.php?f_category_id=&f_report_id=806
### Annex 1: Foodborne virus research projects

This is a provisional list of publicly funded research in the UK since 2005. In some cases the information provided in the table below was taken from the funders website and may not be complete. Some projects are not specifically examining these viruses in the context of food and foodborne transmission.

<table>
<thead>
<tr>
<th>Project Code</th>
<th>Title</th>
<th>Funder</th>
<th>Contractor</th>
<th>Start Date</th>
<th>End Date</th>
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<tr>
<td>FS241043</td>
<td>A systematic review on the survival of norovirus in foods and on food contact surfaces</td>
<td>Food Standards Agency</td>
<td>Leatherhead Food Research</td>
<td>Nov 2012</td>
<td>May 2013</td>
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<tr>
<td>108289</td>
<td>Development of a SELDI-TOF approach for the capture and detection of two major gastrointestinal pathogens: Campylobacter and norovirus</td>
<td>Department of Health</td>
<td>Health Protection Agency</td>
<td>May 2012</td>
<td>Mar 2014</td>
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<tr>
<td>BB/J001708/1</td>
<td>What are the molecular mechanisms underlying the roles of the genome-linked virus protein (VPg) in calicivirus replication</td>
<td>Biotechnology and Biological Sciences Research Council</td>
<td>Imperial College London</td>
<td>Mar 2012</td>
<td>Feb 2015</td>
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<tr>
<td>WT0996</td>
<td>Contamination of shellfish waters with human noroviruses: environmental risk factors and management options</td>
<td>Department of Environment, Food and Rural Affairs</td>
<td>Centre for Environment, Fisheries and Aquaculture Science</td>
<td>Sept 2012</td>
<td>Mar 2013</td>
</tr>
<tr>
<td>BB/I0123X/1</td>
<td>Dissecting the mechanism of translational control during calicivirus infection</td>
<td>Biotechnology and Biological Sciences Research Council</td>
<td>University of Surrey</td>
<td>Jul 2011</td>
<td>Jul 2014</td>
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<tr>
<td>Project Number</td>
<td>Title</td>
<td>Funding Body</td>
<td>Institution</td>
<td>Start Date</td>
<td>End Date</td>
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<tr>
<td>FS231043</td>
<td>Extension to the second study of infectious intestinal disease in the community: Identifying the proportion of foodborne disease in the UK and attributing foodborne disease by food commodity (IID2 Study Extension)</td>
<td>Food Standards Agency</td>
<td>University of Liverpool</td>
<td>Apr 2011</td>
<td>Jan 2013</td>
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<tr>
<td>08/13/35</td>
<td>Can rapid integrated Polymerase Chain Reaction (PCR)-based diagnostics for gastrointestinal pathogens and direct sequence typing of clostridium difficile improve routine hospital infection control practice?</td>
<td>Department of Health</td>
<td>University of Oxford</td>
<td>May 2010</td>
<td>Mar 2013</td>
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<tr>
<td>BB/H011285/1</td>
<td>Understanding the evolution and diversity of viral pathogens using next generation sequencing technologies</td>
<td>Biotechnology and Biological Sciences Research Council</td>
<td>University of Edinburgh</td>
<td>Jun 2010</td>
<td>May 2013</td>
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<td>BB/H012419/1</td>
<td>Understanding the evolution and diversity of viral pathogens using next generation sequencing technologies</td>
<td>Biotechnology and Biological Sciences Research Council</td>
<td>University of Manchester</td>
<td>Jun 2010</td>
<td>May 2013</td>
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<tr>
<td>WQ0220</td>
<td>Catchment modelling strategies for faecal indicators</td>
<td>Department of Environment, Food and Rural Affairs</td>
<td>CREH Analytical Ltd</td>
<td>Sept 2010</td>
<td>Mar 2011</td>
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<tr>
<td>WT0924</td>
<td>The impact of noroviruses on shellfish – The effectiveness of waste water treatment processes on reducing norovirus levels</td>
<td>Department of Environment, Food and Rural Affairs</td>
<td>WRc plc</td>
<td>Sept 2010</td>
<td>Mar 2011</td>
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<tr>
<td>Project Code</td>
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<tr>
<td>FS241006</td>
<td>Development of novel molecular techniques to assess the risk produced by norovirus in shellfish</td>
<td>Food Standards Agency, Scotland (funded under the Post Graduate Scholarship Scheme)</td>
<td>University of Southampton</td>
<td>Sept 2009</td>
<td>Aug 2012</td>
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<td>PB-PG-1207-15212</td>
<td>Cluster randomised controlled trial to test the effectiveness of an educational intervention to promote hand washing in reducing absenteeism in primary schools</td>
<td>Department of Health</td>
<td>University Hospital Bristol NHS Foundation Trust</td>
<td>Sept 2009</td>
<td>Dec 2012</td>
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<tr>
<td>G0800778</td>
<td>Modernising medical microbiology: Establishing how new technologies can be optimally integrated into microbiology</td>
<td>Medical Research Council</td>
<td>University of Oxford</td>
<td>Jan 2009</td>
<td>Dec 2013</td>
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<tr>
<td>041/0025</td>
<td>Survival and spread of norovirus</td>
<td>Department of Heath</td>
<td>Health and Safety Laboratory</td>
<td>Dec 2009</td>
<td>Mar 2010</td>
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<tr>
<td>WT1227</td>
<td>Viruses in raw and partially treated water – Targeted monitoring using the latest methods</td>
<td>Department of Environment, Food and Rural Affairs</td>
<td>Centre for Environment, Fisheries and Aquaculture Science</td>
<td>May 2009</td>
<td>Jun 2011</td>
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<tr>
<td>FS235003</td>
<td>Investigation into the prevalence, distribution and levels of norovirus titre in oyster harvesting areas in the UK</td>
<td>Food Standards Agency</td>
<td>Centre for Environment, Fisheries and Aquaculture Science</td>
<td>Sept 2008</td>
<td>Aug 2011</td>
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<tr>
<td>FS231035</td>
<td>Integrated monitoring and control of foodborne viruses in European food supply chains (VITAL)</td>
<td>Food Standards Agency (European Commission)</td>
<td>Food and Environment Research Agency</td>
<td>Jun 2008</td>
<td>Jun 2011</td>
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<td>Reference</td>
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<td>G0700109</td>
<td>Characterisation of norovirus replication complex formation</td>
<td>Medical Research Council</td>
<td>Imperial College London</td>
<td>Feb 2008</td>
<td>Jul 2011</td>
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<tr>
<td>B17007</td>
<td>A review of the published literature describing foodborne outbreaks associated with ready-to-eat fresh produce and an overview of current UK fresh produce farming practices</td>
<td>Food Standards Agency</td>
<td>Hutchison Scientific Ltd</td>
<td>Sept 2007</td>
<td>Mar 2008</td>
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<td>FT1705</td>
<td>Norovirus stability in food manufacturing and environment</td>
<td>Department of Environment, Food and Rural Affairs</td>
<td>Consortium of research organisations</td>
<td>Jun 2007</td>
<td>Mar 2010</td>
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<td>WQ0111</td>
<td>Faecal indicators losses from farming systems</td>
<td>Department of Environment, Food and Rural Affairs</td>
<td>ADAS Ltd</td>
<td>Jan 2007</td>
<td>Mar 2011</td>
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<td>B17005</td>
<td>Review of the use of irrigation water in UK agriculture and the potential risks to food safety</td>
<td>Food Standards Agency</td>
<td>Robens Centre for Public and Environment Health, University of Surrey</td>
<td>Nov 2006</td>
<td>May 2007</td>
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<td>FS231043</td>
<td>The second study of infectious intestinal disease in the community (IID2 Study)</td>
<td>Food Standards Agency and Department of Health</td>
<td>University of Manchester</td>
<td>Apr 2006</td>
<td>Mar 2011</td>
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<tr>
<td>Code</td>
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<td>S14031</td>
<td>Risk factor in shellfish harvesting areas</td>
<td>Food Standards Agency, Scotland</td>
<td>Scottish Association of Marine Science, Centre for Environment, Fisheries and Aquaculture Science and Centre of Research into Environment and Health</td>
<td>Nov 2005</td>
<td>Dec 2007</td>
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<td>B14004</td>
<td>Generation of an archive of extracted nucleic acid for the IID archived faecal specimens</td>
<td>Food Standards Agency</td>
<td>Health Protection Agency</td>
<td>Jan 2003</td>
<td>Dec 2007</td>
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† The Microbiological Safety of Food Funders Group (MSFFG) report on UK publicly funded research relating to foodborne viruses was published in November 2005 and is available on the Food Standards Agency website at: [http://www.food.gov.uk/science/research/foodborneillness/microfunders/msffg/msffgfbv2005](http://www.food.gov.uk/science/research/foodborneillness/microfunders/msffg/msffgfbv2005)
Day 1  Tuesday 15th January 2013
Room - Booker & Turner Suite

09:30 – 10:30  Registration with morning tea and coffee
Booker & Turner Foyer

SESSION I:  INTRODUCTION

10:30  Chair's opening remarks
Kieron White, WCL

10:35  Food Standards Agency’s welcome and introduction to the conference
Dr Andrew Wadge
Dr Paul Cook

SESSION II:  UNDERSTANDING NOROVIRUS

10:50  What is norovirus?
Professor David Brown, Health Protection Agency

11:05  Norovirus: Outbreaks in the hospital setting
Professor Jim Gray, Norfolk and Norwich University Hospital

11:20  The Second Study of Infectious Intestinal Disease in the UK (IID2 Study)
Professor Sarah J O'Brien, University of Liverpool

11:45  Modelling the foodborne transmission mechanisms for norovirus
Professor David C Lane, Henley Business School

12:00  Interactive session

12:30  Lunch
The Junction Restaurant
### SESSION III: NOROVIRUS METHODOLOGY

<table>
<thead>
<tr>
<th>Time</th>
<th>Presentation Title</th>
<th>Presenter(s)</th>
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<tbody>
<tr>
<td>13:30</td>
<td>Norovirus detection methods</td>
<td>Dr. David Lees, Centre for Environment, Fisheries and Aquaculture Science</td>
</tr>
<tr>
<td>13:45</td>
<td>A critical review of methods for detecting human norovirus and predicting their infectivity</td>
<td>Dr. Angus Knight, Leatherhead Food Research</td>
</tr>
<tr>
<td>14:10</td>
<td>A systematic review on the survival of norovirus in foods and on food contact surfaces</td>
<td>Dr. Angus Knight, Leatherhead Food Research</td>
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<td>14:20</td>
<td>Interactive session</td>
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<tr>
<td>14:50</td>
<td>Afternoon tea and coffee</td>
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### SESSION IV: NOROVIRUS IN THE FOOD CHAIN

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<th>Presentation Title</th>
<th>Presenter(s)</th>
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<tbody>
<tr>
<td>15:10</td>
<td>Viruses in catering environments</td>
<td>Professor Lisa Ackerley, Hygiene Audit Systems Ltd and Salford University</td>
</tr>
<tr>
<td>15:25</td>
<td>The food handler’s role in norovirus outbreaks: Experiences from Gothenburg</td>
<td>Ms. Nancy Nenonen, University of Gothenburg, Sweden</td>
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<tr>
<td>15:40</td>
<td>Interactive session</td>
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<tr>
<td>16:10</td>
<td>Norovirus in fresh produce</td>
<td>Dr. Nigel Cook, Food and Environment Research Agency</td>
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<tr>
<td>16:25</td>
<td>Interactive session</td>
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<tr>
<td>16:55</td>
<td>Norovirus in shellfish</td>
<td>Dr. James Lowther, Centre for Environment, Fisheries and Aquaculture Science</td>
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<tr>
<td>17:10</td>
<td>Sewage discharges and norovirus in the environment</td>
<td>Ms. Elaine Connolly, Department for Environment, Food and Rural Affairs</td>
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<td>17:25</td>
<td>Interactive session</td>
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<tr>
<td>17:55</td>
<td>Chair's wrap-up and introduction to day 2</td>
<td>Kieron White, WCL</td>
</tr>
<tr>
<td>18:00</td>
<td>Close of Day 1 - Drinks reception</td>
<td>Booker &amp; Turner Foyer</td>
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Day 2  Wednesday 16\textsuperscript{th} January 2013
Booker & Turner Suite

08:15 – 08:45  Registration with morning tea and coffee
Booker & Turner Foyer

SESSION V:  INTRODUCTION TO DAY 2

09:00  Chair’s opening remarks
Keiron White, WCL

SESSION VI:  FOODBORNE VIRUSES - AN INTERNATIONAL PERSPECTIVE

09:15  The USDA-NIFA Food Virology Collaborative (NoroCORE): An Integrated, Multidisciplinary Approach to the Study and Control of Foodborne Viruses
Professor Lee-Ann Jaykus, North Carolina State University, USA

09:40  Foodborne viruses: A European Food Safety Authority (EFSA) perspective on methods, limits and control options
Dr Ernesto Liebana, European Food Safety Authority

10:05  International networking to signal norovirus activity
Professor Marion Koopmans, National Institute of Public Health and the Environment, The Netherlands

10:15  Interactive session

10:45  Mid-morning tea and coffee
Booker & Turner Foyer

11:05  Interactive session: Analysing and prioritising norovirus research areas identified

12:10  Lunch
The Junction Restaurant

SESSION VII:  HEPATITIS VIRUSES IN THE FOOD CHAIN

13:10  Understanding Hepatitis E virus
Professor Dilys Morgan, Health Protection Agency

13:30  Hepatitis E virus in the pork food chain
Dr Francesca Martelli, Animal Health and Veterinary Laboratories Agency
13:50  **Hepatitis A virus in the food chain**  
Professor Marion Koopmans, National Institute of Public Health and the Environment, The Netherlands

14:10  **Q&A session on Hepatitis viruses**

14:50  **Chair’s summary of the event**  
Kieron White, WCL

14:55  **Closing Remarks**  
Dr Andrew Wadge

15:00  **Close of Event**