

Monitoring microbial food safety of fresh produce

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Produced jointly by HDC and FSA for field technical staff, this factsheet guides the implementation of practical food safety and risk assessment. It provides background information on important potential microbial contaminants of fresh produce (Figure 1), and also considers the role of microbiological testing of indicator species for water (Figure 2) and fresh produce, and the interpretation of laboratory reports within a food safety system.

Understanding food pathogens

What causes many common foodborne illnesses?

Ingestion of pathogens or toxins that result in infection and/or the production of toxic by-products in the human gut.

What pathogens that can cause foodborne illness are associated with fresh produce?

The number of foodborne illness outbreaks thought to be linked with fresh produce in the UK is relatively small. A report funded by the FSA in 2009 (see Further information) highlighted a small group of bacteria and viruses that have the potential to

cause foodborne illness under certain conditions. This publication focuses on the organisms within that group that may pose a risk in the production of fresh produce under UK growing conditions.

What are bacteria?

- Single-celled organisms that live independently.



1 Example of fresh produce



2 Water sample collected for microbiological testing

- Invisible to the naked eye - they must be magnified 1,000 times to be seen.
- 400 million bacteria are equal to a grain of sugar in size.

To grow, they need:

- Moisture, found in most foods including fruits and vegetables.
- Nutrients, provided by most foods.
- An appropriate incubation temperature.

They are found everywhere:

- In air, soil and water.
- In intestines and faeces of animals and humans.
- On the hands, skin, hair and clothing of people.

It is important to note that not all bacteria are bad, many are vital for our health.

What are viruses?

- Small particles that 'hijack' host cells to replicate themselves.
- Extremely small, much smaller than bacteria (bacteria can also be infected by their own viruses).
- They can be very infectious even at low levels.

To grow they need:

- Living host cells - they cannot grow or reproduce outside of a living (host) cell, ie human gut viruses will not grow, but can survive, on fresh produce.

They can survive in the environment:

- In water courses.
- In soil and raw manure.

Do human gut pathogens grow in fresh produce?

The main concern is surface contamination, although there is some debate about whether food pathogens can grow inside plants.

However, if growers work to minimise surface contamination, they will also reduce the opportunities for pathogens to grow within the plant.

What pathogens are involved?

This publication summarises four bacterial contaminants and two viral contaminants of fresh produce that have been associated with historical outbreaks of foodborne illness linked to produce:

Bacteria

- *Salmonella*
- *E. coli* O157:H7
- *Listeria monocytogenes*
- *Campylobacter jejuni*

Viruses

- Norovirus
- Hepatitis A

Salmonella

What is it?

There are approximately 2,700 serovars of *Salmonella* bacteria, although not all of these are likely to be associated with human illness. In the past, the organism has been associated with foodborne illness from eggs, poultry and dairy products but it can also contaminate fresh produce.

Where does it come from?

Salmonella is found in the guts of animals, especially poultry and pigs but has also been found in reptiles such as lizards. Humans can also carry it sometimes without displaying symptoms.

What effect does it have?

Salmonellosis: nausea, vomiting, abdominal cramps, diarrhoea, headaches, fever. Symptoms start 6–48 hrs after exposure and last for 4–7 days – most people recover fully without antibiotics. Very rarely, it leads to arthritic symptoms after 3–4 weeks.

How long does it survive in the environment?

Salmonella has been shown to survive in soil contaminated

experimentally for two to eight months.

What kills it?

- Nearly all *Salmonella* strains can be killed by cooking (ie 70°C for 2 minutes or equivalent treatments).
- Hand contamination can be removed by thorough hand-washing using scent-free anti-bacterial soap and water (Figure 3).
- Chlorination of water will kill free bacteria in the water but washing in chlorinated water has only a limited effect on the bacteria present on the surface of the fruit or vegetable.
- Low temperatures or freezing will halt growth but won't kill the bacteria.

E. coli O157:H7

What is it?

There are about 1,000 strains of the bacteria *Escherichia coli* (*E. coli*). Most of these occur naturally in the guts of warm-blooded animals and the vast majority are non-pathogenic. There are a few strains that have the ability to produce toxins (these are known as the VTEC strains). *E. coli* O157:H7 is a VTEC strain and is a particular risk as it can cause serious illness at very low contamination levels.

It is important to note that not all *E. coli* cause human illness. Most strains, in fact, help the functioning of the body by synthesising some vitamins and suppressing the growth of harmful bacterial species. As *E. coli* bacteria is a normal inhabitant of animal and human guts, the presence of *E. coli* is used in the food industry as an indicator of faecal contamination. *E. coli* is not usually identified at strain level in routine tests and could be either pathogenic or non-pathogenic.

Where does it come from?

Cattle manure is a major source of *E. coli* O157:H7 – it is found in the manure of about 15% of cattle that are intensively housed. It naturally occurs in a range of animals without showing symptoms, including farm animals and domestic pets.

What effect does it have?

After 3–9 days, an individual may develop severe stomach cramps, bloody diarrhoea, vomiting and dehydration. Symptoms usually pass after 1–2 weeks. In serious cases the infection can lead to kidney failure, strokes and death.

How long does it survive in the environment?

E. coli O157:H7 survives for a considerable time in moist soils at cool temperatures. Research has shown that *E. coli* O157:H7 can survive in moist un-composted farm yard manure for up to two months and in water for up to three months.

What kills it?

- All *E. coli* strains will be killed by cooking (ie 70°C for 2 minutes or equivalent treatments).
- Hand contamination can be removed by thorough hand washing with scent-free anti-bacterial soap and water.
- Chlorination of water will kill bacteria in the water but washing has only a limited effect on the bacteria on the surface of the fruit or vegetable.
- Low temperatures or freezing will halt growth but won't kill the bacteria.

Listeria monocytogenes

What is it?

Listeria monocytogenes is the bacteria that is the principal cause of listeriosis in humans. It has only been recognised as a serious human pathogen since the early 1980s.

Where does it come from?

Listeria monocytogenes is widely distributed in soil and water, although not always at high levels. It is also found in the guts of many animals and it is estimated that up to 10% of humans carry the bacteria in their guts.

What effect does it have?

Listeriosis: After one day to three months, infected individuals may develop mild flu-like symptoms that

will pass after a few days. The disease can progress to more serious illness such as meningitis or blood poisoning, particularly in those individuals that have a reduced immune system and in some cases can lead to death. *Listeria* infection is also a particular risk in pregnant women as it can result in abortion or still birth.

How long does it survive in the environment?

Unlike the other gut pathogens described in this publication, in favourable conditions *Listeria monocytogenes* survives and grows outside the gut and can be difficult to eradicate once it has become established in packhouses and on machinery. *Listeria monocytogenes* can grow across the range of 1–50°C, which means it can continue to replicate in cold stores.

What kills it?

- It resists heat, salt, and acidity much better than many organisms but will be killed by cooking

(ie 70°C for 2 minutes or equivalent treatments).

- Hand contamination can be removed by thorough hand washing with scent-free anti-bacterial soap and water.
- Chlorination of water will kill bacteria in the water but washing has only a limited effect on the bacteria on the surface of the fruit or vegetable.

Campylobacter jejuni

What is it?

There are about 20 strains of *Campylobacter*. The strain normally linked with foodborne illness is *Campylobacter jejuni* which is one of the most common bacterial causes of foodborne illness and is usually associated with poultry and dairy products.

Where does it come from?

Campylobacter jejuni is commonly



3 Hand contamination can be reduced by thorough hand-washing using scent-free anti-bacterial soap and water

found in the guts of poultry, but is also found in the guts of other farm and wild animals as well as humans.

What effect does it have?

Campylobacteriosis: fever, abdominal cramps, and diarrhoea. Symptoms usually occur within 2–10 days of exposure and last 2–5 days. In some people the bacteria can exist in their guts without causing symptoms.

How long does it survive in the environment?

It is reported that *Campylobacter jejuni* declines rapidly on leaves in warm dry conditions but may survive on salad leaves in cooler conditions for 2–3 weeks. Like many bacteria, *Campylobacter jejuni* survives longer in water or cool moist soil and has been detected 1–2 months after contamination.

What kills it?

- *Campylobacter* bacteria are extremely fragile and are easily destroyed by cooking (ie 70°C for 2 minutes or equivalent treatments).

- *Campylobacter* prefer a low oxygen environment, so aerating water may reduce levels in water (Figure 4).

- Hand contamination can be removed by thorough hand washing with scent-free anti-bacterial soap and water.
- Chlorination of water will kill bacteria in the water (Figure 5) but washing has only a limited effect on the bacteria on the surface of the fruit or vegetable.
- Low temperatures or freezing will halt growth but won't kill the bacteria.

Hepatitis A

What is it?

Hepatitis A is one of five viruses in the Hepatitis group (A – E) that attack the liver. Both Hepatitis A and E can be transmitted in faeces, by contaminated water and food, although Hepatitis E is less common.

Where does it come from?

It is carried in the guts of infected humans and shed at high rates in their faeces.

What effect does it have?

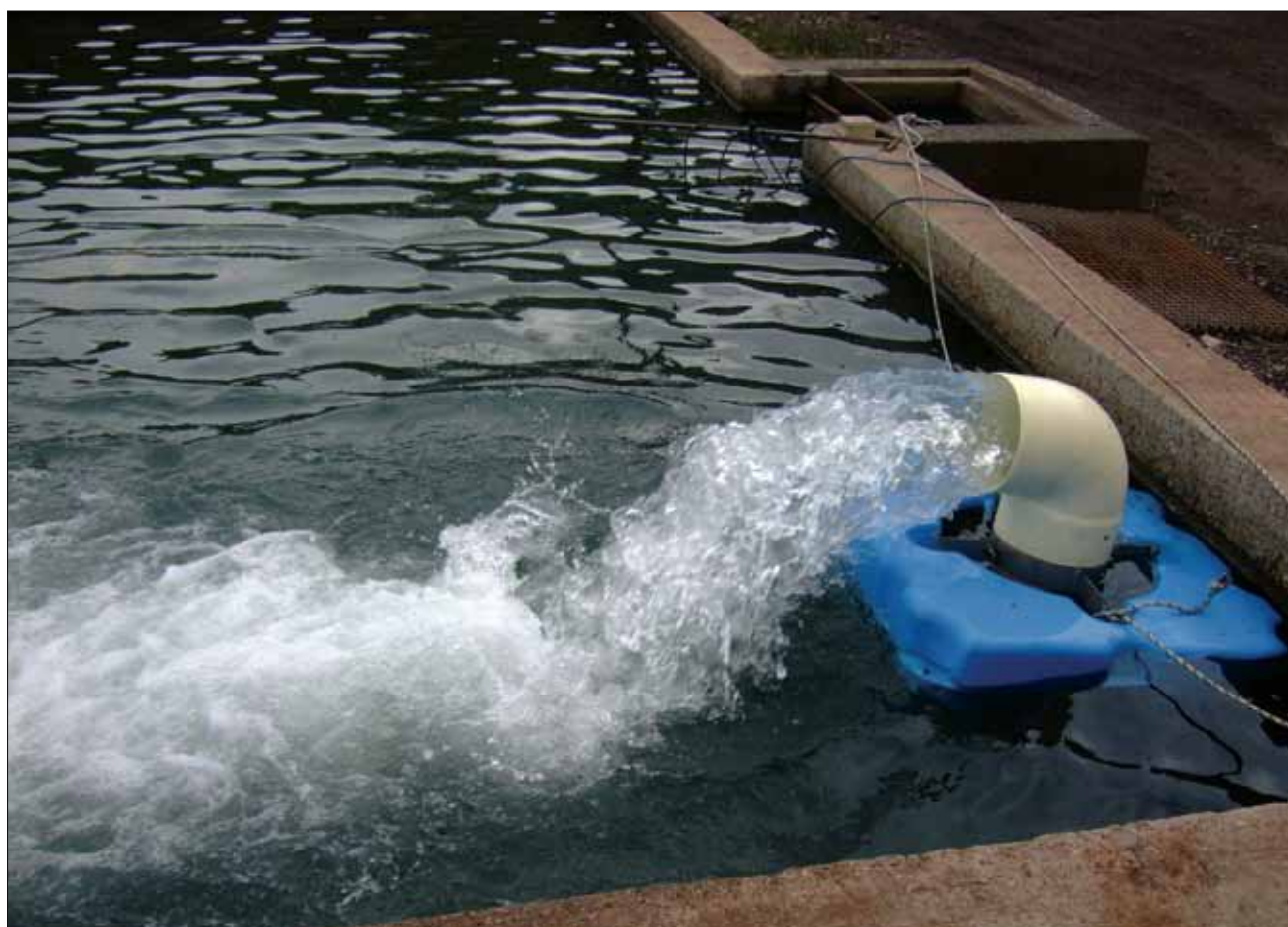
Hepatitis: After 15–50 days, the individual may develop fever, nausea, vomiting, abdominal cramps, extreme fatigue and/or jaundice. The symptoms may last from weeks to months. Hepatitis A does not lead to long-term chronic infection and confers immunity to further attacks.

How long does it survive in the environment?

Studies suggest that Hepatitis A can survive for weeks or months on crops or in soils and up to one month on environmental surfaces at ambient temperatures. Hands contaminated with faeces containing Hepatitis A have been shown to be able to pass on the virus for at least four hours.

What kills it?

- It is possible to kill Hepatitis A with chlorine treatments such as those used in drinking water.



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- Compared with many bacterial pathogens, high cooking temperatures are needed ie 80–90°C for a few minutes.
- Hand contamination can be removed by thorough hand washing with soap and water.

Norovirus

What is it?

Noroviruses are members of a group of viruses called caliciviruses, also known as 'Norwalk-like viruses'.

Where does it come from?

Like Hepatitis, it is carried in the guts of infected humans and shed at high rates in their faeces and can also be present in vomit.

What effect does it have?

Norovirus infection causes gastroenteritis: nausea, vomiting, and/or diarrhoea accompanied by abdominal cramps. Symptoms usually start 1–2 days after

exposure and last for 1–3 days. However, during that period, people can feel very ill and vomit, often violently and without warning, many times a day. Norovirus is highly contagious, with only a small number of virus particles being able to cause infection.

How long does it survive in the environment?

Norovirus can remain unchanged on unwashed hands for at least two hours and remain viable on the surface of cold stored lettuce for at least 10 days and in soil and water for months. The virus can be in faeces and vomit of infected people from the day they start to feel ill to as long as four weeks after they feel better.

What kills it?

- Compared with many bacterial pathogens, high cooking temperatures are needed ie 80–90°C for a few minutes.
- Norovirus is rapidly inactivated by chlorine-based disinfectants (>10 ppm).

- Hand contamination can be removed by thorough hand washing with soap and water.

Controlling food pathogens

All of the pathogens in this publication can be spread through the faecal-oral route, ie faeces. Faeces carrying the pathogen must either directly contaminate the produce or contaminate soil, water, equipment or hands that subsequently come into contact with the produce. In addition, free-living soil or water-borne *Listeria monocytogenes* may contaminate produce through direct contact during production. Norovirus is present in large numbers in vomit.

Factors such as poor staff hygiene, badly composted manure and poor cleaning of equipment or boxes are generally likely to be common routes for contaminating produce.

Thoroughly cooking produce will destroy all of these pathogens.



5 Chlorine injector used to kill bacteria in irrigation water

While care is still needed to minimise routes of faecal contamination in the production of crops that will be cooked, since these can be a source of cross-contamination in the home, these crops pose a lower risk to the consumer.

Produce that is eaten uncooked by the consumer (eg many fruits and salads) is relatively higher risk since washing is not effective at removing pathogen contamination from the surface of produce.

Fresh produce that is used as a raw ingredient in food factories may pass through a decontamination step at the point of transfer from low risk to high care areas, eg a chlorinated water bath, but it is likely that this will only reduce the level of contamination.

As it is not possible to ensure that contaminants are fully eliminated

from uncooked fresh produce the best strategy is to keep it clean.

Given the open field production of much fresh produce, it is unlikely that growers will prevent all possible microbial contamination. However, by following a few key procedures it is possible to markedly reduce the risk of contamination of fresh produce.

Key points

- Consider the potential routes of faecal contamination of the products you grow and how you can manage your crop to prevent contamination. This process is covered in a formal risk assessment process (see Further information section).
- Do not use raw manure on crops that are eaten uncooked.
- Fully compost any manure inputs (Figure 6).
- Prevent faecal contamination of irrigation water sources.
- Minimise contamination risk to crops from adjacent agricultural or industrial activities eg live-stock farms, poultry units or land fill.
- Use potable quality water for post harvest washing or cooling.
- Ensure harvesting equipment is regularly cleaned and stored away from contaminants, ie pest free storage.
- Ensure that staff who handle the crop thoroughly wash hands after eating or using the toilet.



6 Any manure inputs should be fully composted to reduce the risk of contamination in field grown fresh produce

Microbiological testing of fresh produce and water

Although human gut pathogens can be isolated from animal manures, it is important to realise that not all livestock harbour dangerous bacteria in their guts. A survey, funded by the FSA, of UK livestock, showed there was about a one in three chance of the manure harbouring one of the four most important pathogenic bacteria that have the potential to cause an outbreak of foodborne illness in humans (FSA, 2004). Even if pathogens are present in livestock manures, they are likely to be found in quite small numbers — often too few to count by conventional microbiological methods.

What is an indicator species?

Laboratory tests generally do not attempt to count the numbers of specific bacterial pathogens (eg *Salmonella*) in a raw sample due to the difficulties in accurately identifying low population levels. Most tests involve incubating samples in a growth media that is specific for each bacterial group, which allows the target bacteria to multiply rapidly, thereby improving identification. This process is called enrichment. Enrichment test results for specific pathogens are reported simply as 'detected' or 'not detected'. In order to cover all potential pathogens, a grower would need a separate analysis for each pathogen, and under normal production practices nearly all samples would be reported as 'not detected'.

A quicker and more general way to test for potential microbiological problems is to test for indicator bacteria. Indicator bacteria are so-called because they are regularly isolated from test samples in sufficient numbers to be counted. Since most laboratory tests will return a numerical result, indicator numbers can be plotted on a graph showing microbiological trends. Consequently, and in contrast to specific pathogen detection analysis, testing for indicator numbers provides growers with useful

information describing how the microbiological quality of their production site and output changes over time.

A very important point to make clear about indicators is that there are no absolute correlations between the numbers of indicator bacteria in a sample and the likelihood of a pathogen being present. In essence, indicator species give the grower an overview of the microbiological integrity of their production systems.

Which indicator species should you test for?

E. coli

E. coli is an excellent indicator for the faecal contamination of water or fresh produce with human or animal wastes as *E. coli* is found in the faeces of all warm-blooded animals. Since *E. coli* does not survive for extended periods in surface waters or on the surfaces of plants, its presence is associated with a recent contamination event. *E. coli* numbers in water samples tend to increase after heavy rainfall, for example, as livestock manure on land gets washed into streams and rivers. In addition, during very heavy rainfall, sewers and waste treatment facilities can become overloaded and overflow, further contaminating surface waters.

It is important to distinguish between *E. coli* as an overall group of bacteria (most of which are harmless to humans), and *E. coli* O157:H7 which is one individual sub group of *E. coli* that may cause foodborne illness.

Enterobacteriaceae

These are a large and diverse collection of more than 30 different species of bacteria. Despite the name (which means bacteria that live in guts), some members of this group can be found in surface waters and soil, although the majority are associated with human and animal digestive tracts. The numbers of *Enterobacteriaceae* present in a test sample can be thought of as a general indicator of the degree of contamination acquired by fresh produce from faecal material, contaminated water, insects, wildlife, soil and other plants (including some plant pathogens).

Coliforms and faecal coliforms

Coliforms are a subgroup of the *Enterobacteriaceae*. They mostly comprise the *Escherichia*, *Klebsiella*, *Citrobacter*, *Enterobacter* and *Serratia* species, although some other species can grow on the selective growth media that is used to determine coliform numbers. Some members of the coliform group can also be isolated from the environment although they are a better indicator of contamination from faeces than the true *Enterobacteriaceae*.

Faecal coliforms are a sub group of the coliforms and they are isolated using a higher incubation temperature. The underlying strategy of the increased temperature for faecal coliform isolation is that when coliforms have been present in the environment for a while, they begin to lose the ability to grow at the sorts of temperatures found in mammalian and other digestive tracts. The use of a higher incubation temperature selects for bacteria that have been recently deposited into the environment. It is worth noting that a very high percentage (more than 80%) of a faecal coliform count is typically made up of *E. coli*.

Streptococcus* and *Enterococcus

Streptococcus and *Enterococcus* are closely related bacteria that have been used as alternative indicators for faecal contamination of water. The isolation of different species of faecal *Streptococcus* has been used with some success to enable differentiation between animal and human faecal pollution as a way of providing clues to the sources of water contamination. Human-derived faecal contamination contains high numbers of enterococci whereas animal-derived contamination contains high numbers of streptococci.

Listeria

Monitoring the levels of generic *Listeria* as a general hygiene indicator in food production and processing environments has become increasingly popular over the last decade. *Listeria* can be found everywhere in the environment (eg soil, water and also

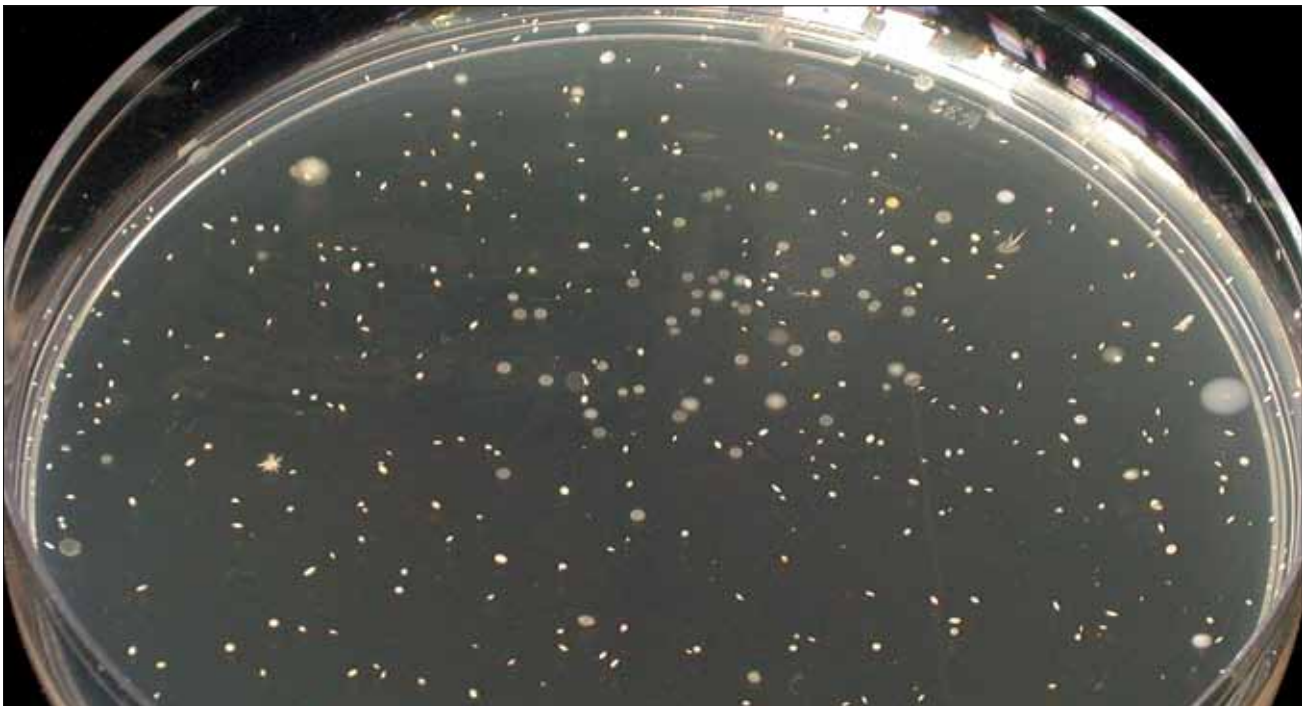
from the drains, floors, walls and equipment of most production and processing areas). Consequently, *Listeria* is considered to be a useful indicator of post-harvest hygiene and cleaning effectiveness.

Total aerobic count

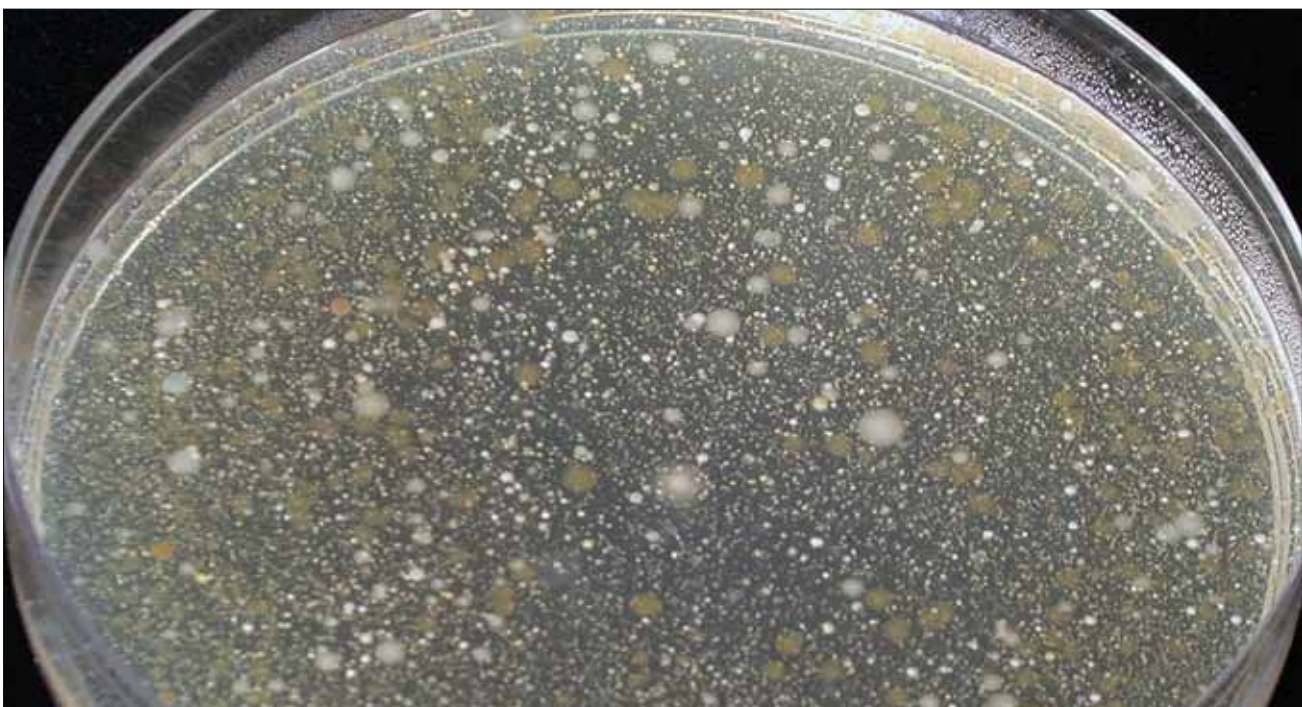
The total aerobic count (TAC) is also known by a number of other names,

including the total mesophilic aerobic count (TMA), the total viable count (TVC), aerobic plate count (APC) and a standard plate count. A TAC attempts to quantify the number of bacteria and fungi in a test sample that can grow at 30°C (a moderate temperature) in the presence of oxygen (Figures 7a and 7b). Thus, despite the use of the word 'total' in the majority of names used for this test, a TAC does not measure

the entire population of bacteria contained within the sample. A high TAC is typically associated with rapid product spoilage and a low shelf life. TACs can be difficult to use as indicators in fresh produce. This difficulty stems in part from the wide variation in counts commonly reported. To overcome this, it is necessary to take logs of each of the counts and use the logged number for the calculation and then return the value to



7a Petri dish showing the range of different bacterial colony morphologies typically observed after incubation of a high dilution (1,000,000 times diluted) sample during a total mesophilic aerobic count laboratory test



7b A lower dilution of water from the same sample (1,000 times diluted) which contains too many individual colonies to count

the original scale using the antilog. Microbiologists call a result calculated in the above manner a geometric mean. For many growers, the additional calculation stages are off-putting and are one reason why TACs are not widely used indicators for fresh produce.

Using ratios of indicators

The ratios of enterococci to other streptococci may have a potential for use as pollution source indicators, but care is needed as enterococci and streptococci populations decline in the environment at different rates.

The ratio of faecal coliforms to faecal streptococci (FC:FS) also has a potential for differentiating pollution sources. For fresh pollution, FC:FS ratios of >4 correlate well with human faeces, and <0.7 is more representative of animal faeces. However, as faecal

coliforms and faecal streptococci die off at different rates, these ratios also change with time.

A summary diagram (known as a Venn diagram) that shows graphically the relationship between the indicators discussed above is shown in Diagram 1.

Laboratory testing and reporting

Samples can be tested by laboratories in three main ways. All three methods rely on the sample being in liquid form. Water samples (Figure 8 - overleaf) may be analysed directly but, prior to testing, soil or produce samples will be first treated to release the bacteria into a weak salt and sugar solution known as a diluent.

1 Filter-based method

The filter-based method (Figure 9 - overleaf) passes water, or diluent, containing the bacteria through

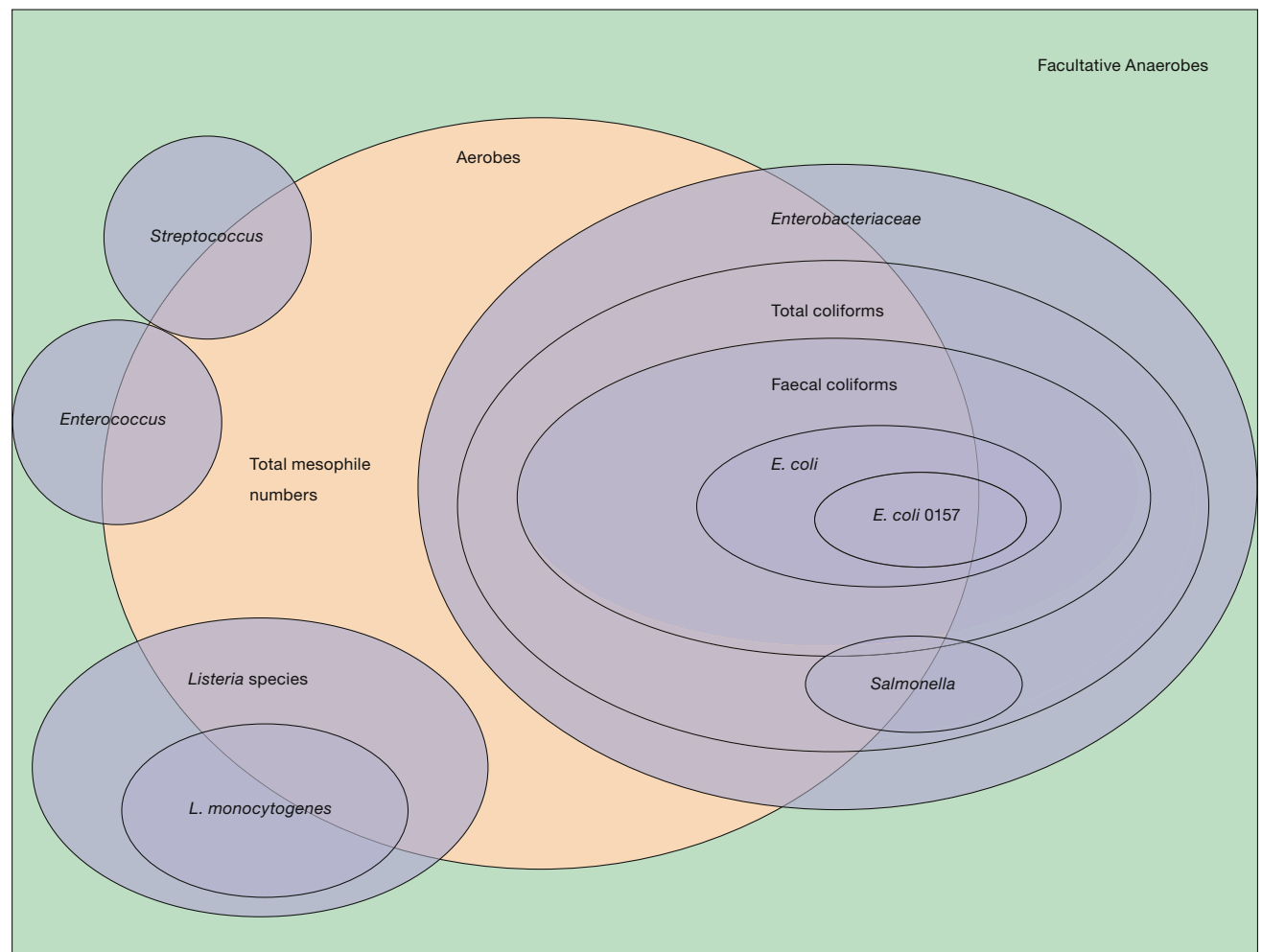
a porous membrane with pores that are too small to allow bacteria through, thereby concentrating the bacteria on one side of the membrane. This method allows a large volume of liquid to be sampled. The membrane is then placed on top of a solid growth medium to allow single bacterial cells to grow into visible colonies that can be counted.

2 Most probable number (MPN)

The MPN method involves separately testing a number of smaller volumes of the sample and estimating the statistically most probable number of bacteria contained within the original sample. MPN is considered to be old fashioned compared with the filter method, but is still useful if the water sample has a large amount of suspended solids that makes filtration difficult.

It is important to note that the MPN method is a statistical estimate of the bacterial numbers within

Diagram 1 The relationships between commonly-encountered bacterial indicators and selected human pathogens



a sample rather than the absolute count made by the filter method. It is usual for laboratories to report an MPN test result as 'MPN CFU/100ml' rather than 'CFU/100 ml' where CFU is the number of colony forming units.

3 Direct plating

Direct plating is commonly used for a count of total mesophilic aerobes contained in soil, produce or poor-quality water where the number of bacteria are relatively high. The technique is basic and simply involves spreading small

quantities of either neat or diluted water directly onto the surface of an agar plate or mixing the sample into liquid agar and allowing it to set.

Irrespective of the test method used, test results for water samples are normally reported as CFU per 100 ml (because it's rare to find a single bacterium in 1 ml of good-quality water). When produce is tested by a laboratory, a 25 g sample is typically used for the test and the result is reported as the number of colony forming units per gram (CFU/g) of food.



8 Water samples can be analysed directly by analytical laboratories



9 A set of typical incubated water filter membranes from a fast flowing overland river before ultraviolet light treatment (left) and after treatment (right)

Interpretation of laboratory reports

As discussed previously, it is important to note that there are no absolute correlations between the numbers of indicator bacteria in a sample and the likelihood of a human pathogen being present. In general, quantifying bacterial indicator species allows growers to develop microbiological profiles of their production systems. When an indicator test result deviates

from an established baseline, it informs growers that something has changed in their production system which may require investigation. By itself, a bacterial indicator testing regime does not assure food safety. Food safety is addressed through implementing a HACCP-based approach to identify potential sources of microbial contaminants and taking action to prevent or minimise the risk. To confirm the presence or absence of a pathogen in a sample, eg Salmonella, it is necessary

to specifically test for individual pathogens.

Indicator testing provides information on the effectiveness of any controls that were in place to protect the growing process. More specifically, different indicator species tell growers about specific aspects of their processes. For example, monitoring the numbers of faecal indicator bacteria on crops informs a grower whether the controls in place to block faecal contamination during crop growing were effective.

Interpreting water samples

In the UK, there are no statutory criteria for indicator bacteria in irrigation waters. However, there are a number of international guidance standards for irrigation water that growers may find useful points of reference when assessing their irrigation water quality. These standards are summarised in Table 1.

Interpreting produce samples

In the UK, there are no statutory criteria for indicator bacteria on unprocessed fresh produce. However, some guidance may be taken from the standards for minimally processed or pre-cut fruit and vegetables (eg bagged salads), in the EC Microbiological Criteria Regulation (MCR) (Table 2). Some retail and food service customers also have their own microbial

specifications and formal response procedures.

Produce that is cooked before consumption, such as potatoes, needs little monitoring as cooking kills potential pathogens.

Does trending data (looking for patterns) give a better understanding of the results?

One-off samples only give a snapshot of microbiological quality at the time the sample was taken. In order to form a picture of microbiological quality over time, it is necessary to plot results to show any trends that may be apparent. The frequency of testing should be more frequent where the grower feels there may be a risk of contamination of the crop and where the crop is to be eaten uncooked by the customer. A typical plot of test results for a surface river is shown in Graph 1 (overleaf).

Important issues relating to laboratories and results interpretation

When trending test results over time, there are a number of considerations to be made. It is important that the laboratory does not change the test method it uses to count indicators or detect pathogens. A test report for a good-quality laboratory will always contain a test method reference, and this reference should be checked to make sure it is the same as previous tests before trending new data with historical data.

If a single water sample is tested using two different test methods, the two results will be different (sometimes very different). Similarly, because test results are sensitive to the equipment used to measure liquids, the brand and type of growth media used and numerous other factors, changing the test laboratory can also result in large changes

Table 1 International standards and guidelines for selected indicator numbers in irrigation water for crops that are likely to be eaten uncooked.

Issuing body	Indicator bacteria	Performance criteria
World Health Organization. Treated wastewater	Faecal coliforms	≤ 1000 CFU/100 ml (calculated as a geometric mean).
State of California, USA. Recycled irrigation water	Total coliforms	≤ 2.2 MPN CFU/100 ml in previous 7 days of test results. No sample to exceed 23 MPN CFU/100 ml in previous month.
Canadian Agriculture Ministry. Irrigation water	Faecal coliforms or <i>E. coli</i> and also Total coliforms	≤ 100 CFU of faecal coliforms or <i>E. coli</i> per 100 ml ≤ 1,000 CFU of total coliforms per 100 ml
Tesco Stores Nurture Scheme. Irrigation water	<i>E. coli</i> and also Faecal coliforms	≤ 1,000 CFU/100 ml for both indicators (calculated as a geometric mean if multiple samples are taken).
Marks & Spencer Field to Fork. Irrigation water	<i>E. coli</i>	≤ 1,000 CFU/100 ml

CFU – colony forming units; MPN – a test result calculated from the most probable number microbiological test method

Table 2 *E. coli* levels as an indicator of process hygiene for minimally processed or pre-cut fruit and vegetables (Europa, 2005).

Pre-cut fruit and vegetables (ready to eat)	Level normally achieved using HACCP and good hygienic practice	Maximum acceptable level
<i>E. coli</i>	100 CFU/g	1,000 CFU/g

in the test results. Furthermore, if the same test method is used, but the tests are undertaken in different laboratories, it is not good practice to mix different laboratories' results on a single trend graph. If the testing laboratory or testing method is changed, a new trend graph should be started.

Laboratories that operate to high accredited standards will have determined the detection limits for all of the microbiological tests that they undertake. Consequently these laboratories will not report low numerical test results as 0 CFU/100 ml. If the detection limit of the test result is 10 CFU/100 ml, and no bacteria grew during the test, the laboratory will report the result as <10 CFU/100 ml, acknowledging that the test method in use is unable to detect below 10 CFU/100 ml.

When trending microbiological results it is standard practice to use half the limit of detection for any low counts reported. Thus a result of <10 CFU/100 ml would be trended as 5 CFU/100 ml. The same approach

and value is generally used for the calculation of any averages from multiple sample tests.

What should a grower do if levels of indicators suggest a problem?

If a grower is finding consistently high levels of indicator species in water sources or on fresh produce this highlights that there is a significant level of faecal contamination in their production system that should be investigated. The following procedure could be observed.

1 Increase frequency and/or scope of testing

If test results suggest a potential problem, the more a grower understands about the causes of the issue the easier it will be to reduce the risk to the customer. The grower should consider increasing the frequency of testing to get a better understanding of the issue. It may help also to test a wider range of samples (eg water

samples) at different points along an irrigation system or adjacent crops to the previously sampled crop.

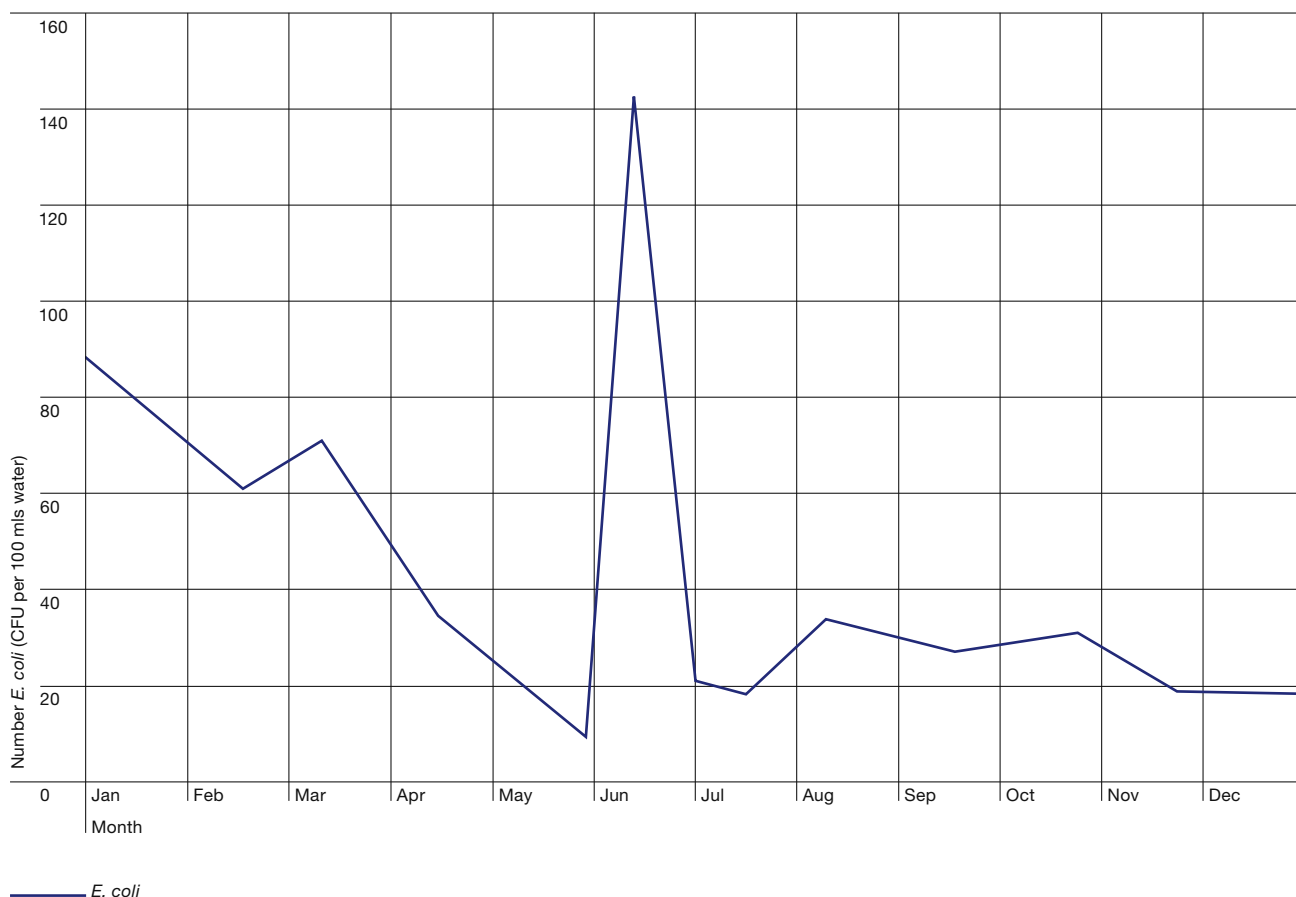
2 Review current risk assessments with emphasis on potential sources of faecal contamination

Current risk assessments related to the issue should be reviewed and used as the basis of an investigation into causes of contamination. If necessary, new risk assessments should be undertaken and in any case reviewed annually. Risk assessment procedures, along with guidance notes for growers for the key areas of manure inputs, water sources, and worker hygiene, are available from the HDC and FSA supported web site (www.safeproduce.eu) from the end of 2010.

3 Take actions that reduce the risk of contamination of crop or product

If the risk assessment concludes that there is a risk of contamination of

Graph 1 A trend of *E. coli* numbers in river water abstracted for the irrigation of crops that are likely to be eaten uncooked



the edible part of a crop, the grower should change production practices to minimise this risk (eg change water source - see below) or alter composting specification.

4 Alert customers

Under UK food law, and EU food hygiene regulations it is an offence to sell or supply food that does not meet food safety requirements. In certain circumstances it may be necessary to alert customers and enforcement authorities to a potential problem with the produce. Some customers specify the notification level of indicator species.

What corrective actions could be implemented if water tests show a variable or consistently high level of indicator species?

The following options could be considered as a way of reducing the risk of contaminating a crop. These suggestions are particularly suited to the highest risk crops (as defined in the Assured Produce Scheme) that are eaten uncooked by the consumer (eg leafy salads).

1 Only use clean water for irrigation within two weeks of harvest

Pathogens decline relatively quickly on the surface of crops, where they are exposed to sunlight and periods of dry weather. Work on survival of human pathogens on salad leaf surfaces (projects FV 292 and FV 292a) has recommended that water free of contamination should be used for irrigation within the two weeks prior to harvest.

2 Change water source

Often the simplest course of action is to switch to an alternative water supply that meets the specification. Although expensive, mains water is considered to be the highest quality irrigation (Figure 10). It is not good practice to dilute out-of-specification water with mains water to bring it back into specification because the high test result indicates a potential problem with the water source that will still exist after dilution.

3 Change method of irrigation

Generally speaking, contaminated water only poses a risk to fresh produce where the irrigation water comes in to direct contact with the edible portion of the crop. The use of

irrigation methods that prevent water coming in to contact with the edible portion of the crop, such as drip or trickle tape, could reduce the risk of lower grade irrigation water leading to a contaminated crop (Figure 11).



10 Mains water is considered to be the highest quality irrigation



11 Drip or trickle irrigation reduces the risk of contamination as the water is unlikely to come into direct contact with the edible portion of the crop

4 Treat water before irrigation

The safest course of action, although expensive and unsuited to treating large water volumes, is to treat the water by buying

(or short-term leasing) an ultra-violet light water treatment unit or a reverse osmosis filtration device (Figure 12). Alternatively, chemical treatments such as

the use of a reactive oxygen-based purifier (eg ozone or hypochlorite) can be added to cost-effectively reduce the bacterial population of smaller volumes of water before application.



12 Reverse osmosis filtration unit used for treating water before irrigation

Further information

Advice for growers on risk assessments

Risk assessment procedures, along with guidance notes for growers for the key areas of manure inputs, water sources, and worker hygiene, are available from the HDC and FSA supported web site (www.safeproduce.eu) from the end of 2010.

General information on fresh produce and food safety

FSA website
(www.food.gov.uk)

HDC website
(www.hdc.org.uk)

Assured Produce Scheme (2010) Generic Protocol Standards (www.assuredproduce.co.uk/resources/000/471/436/Produce_standard.pdf)

Chilled Food Association (2007) Microbiological Guidance for Produce Suppliers to Chilled Food Manufacturers. 2nd Edition (www.chilledfood.org/resources/publications.asp)

USDA (2001) Analysis and Evaluation of Preventive Control Measures for the Control and Reduction/Elimination of Microbial Hazards on Fresh and Fresh-Cut Produce (www.fda.gov/Food/

[ScienceResearch/ResearchAreas/SafePracticesforFoodProcesses/ucm091372.htm](http://www.science.gov/publications/2009/091372.htm))

EC Microbiological Criteria Regulation

CFA/BRC (2006) Guidance on the Implementation of the EC Microbiological Criteria Regulation (www.chilledfood.org/resources/micro-criteria-regulation-implementation-guidance)

Europa (2005) Commission Regulation (EC) No 2073/2005 on microbiological criteria for foodstuffs ([eur-lex.europa.eu LexUriServ/LexUriServ.do?uri=CELEX:32005R2073:en:NOT](http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32005R2073:en:NOT))

Other useful publications

FSA Report B17007 (2009) A review of the published literature describing foodborne illness outbreaks associated with ready to eat fresh produce and an overview of current UK fresh produce farming practices. (www.foodbase.org.uk/results.php?f_category_id=&f_report_id=340)

FSA Report B05003 (2004) Pathogens in organic wastes: their levels and survival both during storage & following application to agricultural land. (www.foodbase.org.uk/results.php?f_category_id=&f_report_id=23)

FSA Report B17002 (2002) Assessment of the risks to food safety associated with spreading of animal manure and abattoir waste on agricultural land. (www.foodbase.org.uk/results.php?f_category_id=&f_report_id=195)

HDC Report FV 248a Assuring the microbiological quality of water used to irrigate salad crops: assessment of the options available.

HDC Report FV 292 Field-grown salads: quantifying the risk of pathogen contamination through irrigation water.

HDC Report FV 292a Field-grown salads: quantifying the risk of pathogen contamination through irrigation water.

Additional information:

Whilst publications issued under the auspices of the HDC are prepared from the best available information, neither the authors or the HDC can accept any responsibility for inaccuracy or liability for loss, damage or injury from the application of any concept or procedure discussed.

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