BACKGROUND INFORMATION

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Enterohaemorrhagic *E. coli* (EHEC) – A problem not specific to sustainable agriculture

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There has been much speculation about the pathogenic EHEC bacterial strain that has tragically claimed the lives of more than 30 people so far in Germany. Meanwhile, the transmission pathways have for the most part been identified. The origin of the pathogen, however, is largely unclear.

In the context of the EHEC outbreak there have been debates as to whether certain agricultural methods (e.g. mixed holdings including both livestock and crop production, or the use of organic fertilizers for vegetable production) or certain sanitization methods for fresh consumable products (such as the use of organic acids, a mild treatment that leaves fewer residues) may increase the risk of infection.

This document does not address the current epidemiological situation of the outbreak in northern Germany. Its purpose is rather to provide background information on the question of how sustainable agricultural methods based on nutrient cycling deal with pathogens that can be transmitted from animals to humans (zoonoses).

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1. What is EHEC?

Enterohaemorrhagic *Escherichia coli* (EHEC) bacteria are strains of the intestinal bacterium *Escherichia coli* which can cause dangerous bloody diarrhoea in humans. These bacteria can produce Shiga toxin, which is why they are also known as Shiga toxin-producing *E. coli* (STEC). Carriers of these bacteria are primarily cattle, sheep and other ruminants. Roe deer, wild boar, wild birds, pigs and chickens may also excrete EHEC, albeit to a lesser degree. The principal transmission routes to humans include contaminated food items such as uncooked meat and raw vegetables, fruit and unpasteurized milk products, contaminated drinking or bathing water, or direct contact with infected animals. The mostly harmless *E. coli* bacteria can undergo significant changes due to crossing or mutation and thus lead to unpredictable problems. Intensive livestock rearing appears to favour the development of problematic strains of bacteria.

2. General food hygiene regulations

› Organic and non-organic foods are subject to the same hygiene regulations and food legislation

Food legislation aims to ensure that food is safe for human consumption. Its provisions apply without compromise to non-organic and organic foods alike.

Preventive measures to ensure food safety include:

- Prevention of primary contamination.
- Prevention of secondary contamination in the production and processing of foods as well as during storage and transport.
- Destruction of pathogens using heat (cooking, frying, pasteurizing, sterilizing).
- Storage of foods or prepared meals under conditions which do not allow for the propagation of pathogens (cooling, freezing, or keeping hot at above 65°C); use-by dates.

Nowadays, food is generally very safe due to legislation, government controls and individual quality assurance measures (HACCP) at farm/company level. Nevertheless, consumers also carry a degree of responsibility and are advised, for example, to wash or, where appropriate, peel fruit and vegetables prior to consumption.

3. Scientists have been studying the possible transmission of *E. coli* bacteria to food for many years

As organic farming is particularly quality conscious, for many years now scientists have been analysing potential risks and specific measures to further mitigate such risks. In the context of the EU QualityLowInputFood[1] project several European research groups studied potential quality impairments in vegetable and livestock production. All the results have been published (Wiessner et al., 2009; Zheng et al., 2007). Other scientists compared more environmentally-

[1] Information on the QualityLowInputFood project can be found at http://www.qlif.org/objective/safety1.html

friendly post-harvest treatments of ready-to-eat mixed salads and developed entirely new sanitization methods (Ölmez et al., 2008).

The transnational research project PathOrganic[2], which integrates a number of different research groups, has over the past three years been addressing the issue of the risk of enteropathogens in slurry or farmyard manure and vegetables respectively and has developed a set of recommendations.

From the findings to date it can be concluded that while EHEC is a residual risk of the entire food production chain (see section 2), organic farming does not carry a greater risk of transmission than non-organic farming.

These results, which are based on numerous research projects, are further supported by food inspections. For example, in 2007 only one case out of a total of 26 *E. coli* outbreaks in the European Union was due to the consumption of organic produce, in this case sausages (EUROPEAN FOOD SAFETY AUTHORITY, 2009).

4. One important cause of the EHEC problem: Intensive livestock production

- Feeding in accordance with species-specific needs drastically reduces EHEC in livestock faeces
- Fewer EHEC bacteria are found in livestock farm waste from organic farms
- Intensive livestock rearing results in greater use of antibiotics and formation of resistance

In today's farming world, concentrate feeds are a significant component of cattle rations for the purpose of obtaining high yields. Cattle faeces contain much higher levels of EHEC and other acid-resistant *E. coli* bacteria if concentrates are fed, as the latter lower the pH in the animals' digestive tract. The feeding of roughage, however, drastically reduces the numbers of EHEC bacteria in cattle faeces as this results in a pH that is an unfavourable environment for EHEC bacteria (DIEZ-GONZALEZ et al., 1998; CALLAWAY et al., 2003). Faecal *E. coli* bacteria from cattle fed large amounts of feed grain are not sufficiently killed off in the gastric juices of the human stomach and thus reach the intestines where they may cause diarrhoea. Such acid-resistant bacteria, of which EHEC is an example, survive the "acid shock" in the human stomach. The acid-sensitivity of *E. coli* bacteria from cattle fed roughage is 1000 times greater (DIEZ-GONZALEZ et al., 1998). To feed ruminants such as cattle and sheep in accordance with their species-specific needs is an important concern of organic farming. The ruminants' large rumen is naturally designed to digest large amounts of roughage (grass, clover, herbs). Sixty-eight percent of the global agricultural area consists of permanent grassland (FAO statistic). Ruminants can render such lands accessible to human food production and therefore play a very important role in food security. Organic farming standards take account of this fact and focus consistently on feeding with roughage. Individual private labels have very strict standards. Bio Suisse standards for example prescribe a minimum of 90% roughage for cattle. Thanks to this type of feeding regime, livestock farm waste from organic farms tends to contain fewer EHEC bacteria. The transnational PathOrganic research project has confirmed this tendency. Current

[2] Information on the PathOrganic project can be found at http://www.icrofs.org/coreorganic/pathorganic.html

research projects on commercial farms therefore aim at exploring ways of rearing cattle largely without concentrate feeds[3].

It has also been shown that stress increases the risk of high shedding rates of EHEC (CHASE-TOPPING et al., 2007, MENRATH et al., 2010). Ethologically sound husbandry, including appropriate stocking rates and thus reduced stress, is a core characteristic of organic livestock systems.

While antibiotic-resistant bacteria are mostly the result of erroneous medical treatment in humans, the treatment of livestock also needs to be taken into account as a relevant source. Despite the fact that cattle generally do not suffer any effects from infections with EHEC, they are considered the main source of these bacteria and shed *E. coli* at a frequency that is often underestimated. The extreme intensification of livestock rearing systems has led to a situation where the preventive use of antibiotics has become an essential component of livestock health systems. This is particularly the case in livestock fattening systems, where antibiotics are used to prevent infections resulting from ethologically unsound practices (excessive stocking densities in indoor housing). Preventive use of antibiotics is also practiced in dairy production. The milk of dairy cows treated with antibiotics is usually fed to calves or pigs. As part of a national research project, Swiss scientists have shown that the intestinal bacteria of a group of calves fed in this manner developed complete resistance to the antibiotic used (SCHÄLLIBAUM, 2007). The intensification of livestock breeding and livestock management systems with a view to high performance (both in livestock fattening and dairy production) has led to a situation where intensive “modern” livestock health management has come to rely more and more heavily on the use of antibiotics as the animals become increasingly more susceptible to disease (e.g. ALALI et al., 2004; ALEXANDER et al., 2008). This is a worrying trend as it leads to the displacement of harmless intestinal bacteria that are sensitive to these antibiotics, due to selection for antibiotics-resistant, uncontrollable pathogens that pose an enormous risk to humans. In organic farming, however, all preventive uses of antibiotics are prohibited.

Due to its systems approach, organic farming can significantly lower the risk of the transmission of pathogenic micro-organisms to humans. This is achieved by adopting feeding and husbandry methods which fulfil the welfare requirements of livestock and by proper handling of veterinary medicines.

5. Why is it important to close nutrient cycles with organic fertilizers?

- Organic fertilizers promote soil fertility
- Recycling instead of depletion of non-renewable resources (e.g. phosphorus)
- Sustainable agriculture reduces greenhouse gas emissions (e.g. nitrous oxide)

Organic fertilizers, especially farm waste such as farmyard manure, slurry and compost, are valuable nutrient sources for agricultural production. In many developing countries and emerging economies, agricultural production would grind to a halt if farm waste was no longer used (MCINTYRE et al., 2009) as commercial fertilizers are in limited supply and often unaffordable. Organic farming builds on this traditional pattern of fertilizer management (TROELS-SMITH, 1984), which both recycles plant nutrients such as nitrogen, phosphorus and potassium to the

[3] Information on the ‘Feed no Food’ project can be found at www.fibl.org/de/schweiz/forschung/tiergesundheit/tg-projekte/feed-no-food.html

soil and builds soil fertility. The majority of farm holdings in Central Europe combined crop and livestock production into the 1960s. In the meantime, however, there has been a considerable degree of specialisation into different types of farm enterprises in the industrial countries and main food producing countries Germany, France, Great Britain, Italy and Spain, and livestock rearing and crop production have increasingly become decoupled (STATISTISCHES BUNDESAMT, 2011). Mixed farm enterprises primarily remain only in the organic farming sector. This is due to the awareness of nutrient cycles that is inherent in organic management, i.e. the utilization of nutrients from organic crop and livestock wastes on the holding itself for the purposes of crop production (LAMPKIN, 1992), which makes it possible to minimize the use of industrially produced fertilizers or other nutrients brought in from outside the holding.

Especially with a view to dwindling phosphorus resources this approach is the more sustainable one. Since in industrial-type farming livestock and crop production are decoupled in both spatial and operational terms and since mineral phosphorus fertilizers are – as yet – an affordable commodity, these bought-in fertilizers have primarily been used over the past decades. The massive use of fossil fuels for the production of synthetic fertilizers and the climate-relevant nitrous oxide emissions resulting from the use of these fertilizers in crop production should be reason enough to question the current practices in terms of the use of nitrogen fertilizers in industrial-type farming (see, among others, IPCC, 2007). With a view to reducing nitrogen inputs from agricultural production into waters and the atmosphere, sustainable land-use methods such as organic farming are widely considered to be the more future-proof option (IPCC, 2007; IAASTD, 2009). Organic farms generate practically no excess nitrogen, as the number of livestock kept is conditioned by the amount of land available and the application of livestock-generated fertilizer is regulated by law (EU Regulation 837/2007). The levels of nitrogen fertilizers used in organic farming are significantly lower than the levels associated with the prevalent farming systems.

6. What are the benefits of using organic fertilizers?

› Micro-organisms enable the conversion of plant material into milk and meat
› Micro-organisms stabilize soils

Complex biological systems, in which micro-organisms (predominantly fungi and bacteria) play an important role, are inherent to both agricultural food production and industrial food processing. For example, the rumen microbial communities of cattle, sheep and goats enable the conversion of indigestible, cellulose-rich plant material into animal protein – the basis of meat, milk, wool and leather. The soil is also alive with microorganisms and that is a good thing: a handful of soil contains more organisms than there are humans on earth. Micro-organisms such as bacteria and fungi dominate the soil in terms of mass (TORSVIK and OVEREAS, 2002). These micro-organisms stabilize the soil structure, decompose extraneous substances such as pesticides, convert organic matter and thus supply nutrients to plants, and play an essential role in humus formation.

Farmyard manure, compost and slurry contain an even greater amount of micro-organisms (in terms of dry matter) since the rich supply of nutrients stimulates microbial growth. The application of these farm wastes on agricultural lands therefore transfers not only the nutrients contained in these fertilizers to the land but also the microbes these materials contain as well as microbes derived from cattle's digestive tracts (GATTINGER et al., 2007). Moreover, the energy-rich organic compounds contained in farm wastes stimulate the growth of soil-borne micro-organisms. Regular applications of farm wastes thus promote humus formation and soil life, as many long-term trials have demonstrated (MÄDER et al., 2002; GATTINGER et al., 2007).

7. What are the risks associated with using organic fertilizers?

- Thermal treatment of farm wastes greatly reduces risks
- Unfermented, unstored slurry poses a greater risk

The type of organic fertilizer used has an impact on the occurrence of human pathogens – germs that cause disease in humans – (see e.g. PathOrganic project, publications in progress; FRANZ et al., 2008). During storage and composting, farmyard manure and composts heat up to temperatures of well over 40°C which cause these germs, all of which are mesophilic, i.e. thriving best at moderate temperatures, to die off. The transmission risk of these farm wastes can therefore be considered to be low (ERICKSON et al. 2009). Applications of fresh animal dung or (non-aerated and unstored) slurry are different, as these have not gone through a sanitizing heating phase. Laboratory experiments have shown that the highly pathogenic *E. coli* strain O157:H7 can survive for up to 200 days in soils to which non-aerated cattle slurry has been applied (FREMAUX et al., 2008). Both abiotic (pH, temperature, moisture) and biotic (composition and diversity of microbial communities) soil parameters impact on the survival of *E. coli* O157:H7 in the soil (VAN VEEN et al., 1997). However, it must be stressed that soils which are well-aerated due to cultivation and the growth of plant roots are not a preferred habitat for bacteria of this kind as all four of the human pathogens mentioned are considered to be facultative anaerobic. A Dutch study of 18 soils, each under organic and non-organic management, found no difference in the survival rates of *E. coli* O157:H7 following the application of cattle slurry to soil material where bacteria of this strain had been added to the slurry (FRANZ et al., 2008). Pathogen-suppressing, sanitizing conditions can be achieved by regular applications of organic fertilizer such as farmyard manure or compost (VAN BRUGGEN et al., 2006).

8. Fertilizer management in vegetable production

- Farm-derived fertilizers are incorporated into the soil prior to planting and are not applied to the plants
- Obligatory application periods and waiting periods apply
- Water is drawn from safe sources

Vegetable production is particularly susceptible to the transmission of potential human pathogens into the human food chain as, unlike tillage crops, the harvested crops receive little or no post-harvest treatment and are eaten fresh. Organic fertilizers are used in both organic and non-organic vegetable production but their use is subject to application periods and waiting periods as set out further below. GlobalGAP certified producers (GlobalGAP: standards for food retail chains) are not permitted to apply fertilizers to standing vegetable crops, i.e. farm wastes such as slurry, farmyard manure or compost must be applied prior to sowing or planting and must be incorporated into the soil (GlobalGAP / Fruit and Vegetable / 3.2.1). Holdings that are not GlobalGAP-certified adhere to the same practices. In recent years, the use of bought-in processed organic fertilizers has become more widespread in organic vegetable production because these are easier to apply, contain defined levels of nutrients and are free of enterobacteria and human pathogens as they have been pre-treated (EC Regulation 1069/2009). Moreover, many specialized organic vegetable producers do not keep livestock. However, as bought-in organic fertilizers are very expensive, green manures as a third option are also used in organic vegetable production. Yet bacterial contamination can also be caused by irrigation water. Surface waters, e.g. ponds or drains located near pasture lands may contain pathogens. In one well-documented case of the contamination of spinach with EHEC bacteria (BENBROOK 2009), contaminated irrigation water was the probable cause. Nowadays, vegetable producers must draw irrigation water from safe sources or they must supply regular water testing results.

9. Precautionary measures and good farming practice

Findings from the PathOrganic project and the literature (e.g. KÖPKE et al. 2007) are currently being used to draw up recommendations for the use of farmyard manure and slurry in vegetable crop rotations. Any applications after sowing or planting are strongly inadvisable. Manure should be composted if at all possible. If slurry is used it should be well stored in separate tanks. Slurry which is already fermented should not be mixed with fresh slurry. A four-month waiting period is recommended between applications of slurry or fresh farmyard manure and the planting of a new crop of vegetables which has a short growing period and is intended for raw consumption. There should be a waiting period of six months prior to sowing or planting vegetables intended for ready-made salads. Irrigation water should be drawn only from safe sources and it must be ascertained that livestock faeces can not drain into vegetable plots from neighbouring fields.

10. Hygiene in processing

› Organic farming uses organic acids for disinfection
› Research has already developed and is in the process of developing additional measures

There are differences between organic and non-organic post-harvest processing of foodstuffs. For environmental reasons, different types of disinfectants and different techniques are used to disinfect seed (important for e.g. sprouts) and water used for washing food (primarily vegetables). Permitted additives for organic foodstuffs are organic acids such as ascorbic acid (E 300), citric acid (E330), or lemon juice concentrate. Permitted substances for cleaning organic foods are peracetic acid and hydrogen peroxide. Scientific research has show that the substances permitted for use in the processing of organic foodstuffs are sufficiently effective to ensure food safety (ÖLMEZ et al. 2008).
In non-organic food processing, chlorine dioxide is primarily used. It is a potent oxidizing agent and is also used, for example, to bleach paper or disinfect water. It has also been known for 25 years that chlorine dioxide is one of the substances involved in depleting the earth's ozone layer.

Ongoing research is assessing the options for using ozone (see www.qlif.org) and other oxidizing techniques to sanitize organic foods. However, these techniques are not quite yet workable and require further scientific clarification.

11. Conclusions on the risk potential in organic farming and on the use of organic fertilizers

- Organic foods are not subject to greater bacterial contamination
- Organic feeding standards ensure presence of fewer pathogenic bacteria
- High soil fertility and professional treatment of farm-derived fertilizers ensure swift destruction of pathogenic bacteria

The above explanations clearly show that there is at present no scientific evidence for a greater contamination of organic foods with human pathogens compared to non-organic foods, despite the fact that the use of organic fertilizers is a central element of organic farming. This is due in part to the fact that the entire production process consisting of livestock rearing, manure management, soil management, growing and cultivation, processing, packaging and sales has been subject to the relevant hygiene requirements for a long time, with the result that risks arising from the use of farm wastes have largely been eliminated. Organic farmers in particular are highly knowledgeable with respect to the correct management of farm-derived fertilizers. The feeding of a high proportion of roughage, as prescribed in the organic standards (up to 90% roughage in daily rations under some private organic labels), ensures a reduced input of *E. coli* bacteria into slurry and farmyard manure stores from the outset. The generally favourable physical and microbial soil fertility on organic farms ensure the swift elimination of potentially introduced *E. coli* populations.

A ban on the application of organic fertilizers on agricultural lands would not eliminate the general risk of transmission of human pathogens onto foods, as *E. coli* and other bacteria can also occur in irrigation water or drinking water as long as livestock is kept anywhere. Nevertheless, all measures that help eliminate the contamination of foods with human pathogens must be implemented.
Given dwindling nutrient resources, a growing world population, declining food security and advancing climate change, there is no alternative to recycling plant and livestock residues onto lands which are directly or indirectly destined for food production. To the contrary, numerous scenario studies show that in many areas the available quantities of plant and animal residues will not even suffice.

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