Good Agricultural Practices: organic and inorganic fertilizers [1]

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1. Introduction

Generally, fields used for cultivation purposes need an extra supply of fertilizers to enrich the soil. Fertilizers are added to provide the soil with the nutrients necessary for plant growth. The use of fertilizers ('plant nutritionals') is a common practice to increase the quality of the soil, and consequently the quantity and quality of the fruits and vegetables grown on it. Fertilizers are often divided into two main groups, organic and inorganic, depending on the source of the material.

2. Organic Fertilizers

Organic fertilizers are derived from plant or animal materials. Raw materials commonly used in their production include:

- Animal manure
- Post-harvest plant material
- Organic waste
- Bio solids / sludge (human waste)

The animal manure, post-harvest plant materials or organic waste are converted into compost. When properly treated, organic fertilizers have many advantages to public health. For example, the production process eliminates waste material that otherwise could cause microbial contamination of the environment.
In 1992, a large amount (1,029,555 tons dry solids) of sewage sludge was generated in the UK. More than 460,000 tons were applied to agricultural land (Maule, 2000). In comparison, the volume of animal waste from farms that is applied to the land is even

greater. In the UK, some 21 million tons (dry solids) of farm-animal waste are spread annually on the land (ACMSF, 1999).

2.1 Associated Risks

Human and animal faecal materials are important sources of microbiological and chemical contamination for the produce.

Micro-organisms linked to these sources include *Salmonella* and *Enterococcus,* and other intestinal bacteria. One of the most infectious organisms found in animal manure is *Escherichia coli* O157:H7, which usually originates from ruminants, such as like cows, sheep and deer.

Other significant microbiological hazards found in faecal material include *Salmonella* and *Cryptosporidium* (FDA, 1998).

Usually, vegetative bacterial pathogens and viruses decline in numbers within a few days of their introduction into the soil (Watkins and Sleath, 1981; Van Renterghem *et al.*, 1991; Dowe *et al.*, 1997) or onto the plant surfaces (Kott and Fishelson, 1974; Ward and Irving, 1987). However, they may survive (in low numbers) for several weeks or months (Watkins and Sleath, 1981; Al-Ghazali and Al-Azawi, 1990; Dowe *et al.*, 1997). Survival in the soil is influenced by several factors, e.g. soil type, humidity, temperature and microflora (Tierney *et al.*, 1977; Dowe *et al.*, 1997). *E. coli* O157:H7 survived in bovine and ovine manure from several weeks to 12 months, depending on the environmental conditions (Kudva *et al.*, 1998; Fukushima *et al.*, 1999). Therefore, animal manure and solid biological waste may provide safe, effective fertilizer only when it has been properly treated. If the treatment is inadequate (or there is no treatment), the risk of contaminating fruit and vegetables with pathogenic organisms is extremely high.

The risk of contamination from the manure and during its application to crops depends on various factors, including soil type, manure application rate, pH of the soil, composting method and time of application. Continued application of untreated manure could lead to extended survival and build-up of pathogens which increases the risk of both contamination at that site and its spread to nearby sites.

In addition to microbial hazards, the use of solid biological waste on land can also introduce chemical hazards, such as heavy metals and toxic organic compounds. These materials may accumulate to levels that will be harmful to plants grown on the land. Another harmful effect from improperly treated manure is its impact on water quality due to the release of oxygen-demanding substances, suspended solids and nitrogen.

2.2 Treatments to reduce the risks

To convert organic waste into a safe fertilizer (compost), 'Good Manufacturing Practices' should be followed to reduce the presence of pathogenic bacteria. Composting is a natural, biological process by which organic material is decomposed. Bacteria and fungi that ferment the organic material and reduce it to stable humus carry out the composting process. Because the fermentation process generates much heat, it reduces or even eliminates biological hazards. If the heating process is managed carefully it will kill those foodborne pathogens that do not form spores (Strauch, 1991). However, the adequacy of existing methods of composting and associated regulations needs to be reviewed (Tauxe *et al.*, 1997).

The USDA´s Natural Resources Conservation Service (NRCS) has prepared guidance on the development and use of a composting facility. This document is available via the internet at: ftp://ftp.ftw.nrcs.usda.gov/pub/nhcp/pdf/317.pdf (accessed 7/01).

Composting treatments can be divided into two groups, passive and active treatments.

Passive composting treatments are based on maintaining organic waste under natural conditions. The compost piles are not turned; free oxygen in the piles is quickly used up, resulting in anaerobic conditions, which slow the composting process. However, environmental factors, such as temperature, humidity, and ultraviolet radiation, given enough time, inhibit the growth of pathogenic organisms and eventually destroy them. The biggest obstacle to this approach is that it takes a long time to reduce significantly the number of pathogens in the material. Determination of the critical time for this process to take place is difficult. The amount of time needed depends on the climate, region and season, as well as the source and type of manure or organic waste used. Due to these uncertainties, passive composting treatments are not recommended.

Active composting treatments are those in which the piles of material are handled actively and conditions are created to speed up the process of converting waste materials into compost. Active treatment is the process most widely used by farmers today. The compost piles are turned frequently, or other means of aeration are provided to maintain adequate oxygen (aerobic) conditions within each pile. Temperature and moisture levels in the piles are monitored and supplements are added when necessary to provide optimum moisture and a proper carbon/nitrogen ratio for complete composting.

The composting process is complete when the pile stops heating. Under appropriate conditions, the high temperature generated during the fermentation process destroys most of the pathogens in a relatively short time.

Microbial analysis of the compost may be carried out to determine the effectiveness of the process in eliminating pathogenic bacteria. *E. coli* and *Salmonella* are generally used as indicators and, if the organisms are still present in the compost, the fertilizer should not be used for crops, until an additional treatment of the fertilizer has been applied Additional treatments, such as pasteurization, drying with heat, anaerobic digestion, stabilization with alkali, aerobic digestion or a combination of these methods may be used to speed up the composting process. There are several procedures for active composting treatments. A recommended procedure was published by Ballesteros-Sandoval (1999).

2.3 GAP in the management of organic fertilizers

To ensure that pathogenic microorganisms do not reach fruits and vegetables and, ultimately, consumers, it is necessary to observe GAP when organic fertilizers are prepared and applied.

Manure should be suitably contained before treatment. The location for storage and treatment of animal manure should be as far away as possible from produce growing areas. Barriers or some type of physical containment should be used in manure storage areas to prevent contamination of produce or production areas by pathogens. These can be spread from the stored manure by rain wash, subterranean water-flow or wind. Contamination of groundwater supplies can be minimized by storing animal manure on a cement floor or in special holes lined with clay.
Rainfall on manure piles can result in a run-off containing pathogenic bacteria that can contaminate the fields, equipment, etc. Therefore, manure piles should be covered with plastic or other materials and/or stored underneath a raised shed.
Equipment (tractors) coming into contact with untreated manure can be a source of contamination for the produce and/or the production area. Equipment should be cleaned with high-pressure water or steam before it is allowed into the production area. In a similar way, personnel handling manure should not enter the growing fields without paying attention to personal hygiene.

Treated manure should be kept covered and away from waste and garbage to prevent recontamination by birds or rodents. It should be stored well away from the growing fields and separated from product packaging material, so it will not contaminate the fresh produce, water sources or packaged products.

Properly-treated organic fertilizer should be applied prior to planting or during the early stages of plant growth. It should be applied near the roots and covered with soil. Organic fertilizers should NOT be used when the fruit or vegetable is nearing maturity or harvest. Maximum time should be allowed between application and harvest of the produce. It is also suggested that crops on adjacent fields are produced in a way that avoids use of organic fertilizers when other, nearby crops are already nature or near harvest.

In assessing the severity of the risk of biological contamination, the type of fruit or vegetable that is being produced should be taken into account.
Produce that grows in or on the surface of the soil is more susceptible to contamination, while that growing close to the ground is more likely to be contaminated by splashing during rain or irrigation. Fruits and vegetables produced on plants where there is no direct contact with the soil are less susceptible to contamination, provided that these falling to the ground are not included in the harvest. The risk of contamination increases when the characteristics of the fruit or vegetable make it easy for dust or bacteria to adhere to plant surfaces.

2.4 Untreated animal manure

The application of untreated animal manure (without composting) during the cultivation period is not recommended because the risk of contamination is greater than with treated manure. Although raw manure is never recommended as a fertilizer, it is still used in some regions. Where that occurs, the manure should be introduced into the ground during soil preparation and prior to planting. Microorganisms in the soil may reduce the survival of pathogens in the manure; however, time is a critical factor. The manure should be incorporated into the soil and the ground turned periodically to facilitate pathogen reduction. Maximum time should be allowed between the application of manure and planting. The survival period for pathogenic bacteria in manure is unknown, but some researchers estimate that, depending on environmental conditions, it can extend to a year or more.

2.5 Recommended controls and records

Keeping complete records of fertilizer preparation and use is part of a GAP program. This includes information about the preparation of the fertilizer, the source of the starting material, details of composting procedures, and the results of microbiological tests on the composted material. Records should also be kept on the dates, amounts and methods of applying the fertilizer, the person responsible for the application etc. These records will help to verify that appropriate steps were taken to ensure the safety of the produce and to trace both the origins of the used materials used and other products from the growing area, when required.

Suggestions for information to be recorded:

- Origin of the organic materials used
- Date composting process started
- Treatment applied
- Turning of windrows (minimum five times)
- Temperatures during composting (daily temperature readings of 55°C (131°F) or higher should be attained).
- Period at 55°C (131°F) or higher for windrow composting.
- Source and physical make-up of composted material
- Amount used
- Place of application
- Date of application
- Method of application
- Person responsible for application
- Microbiological testing (Acceptable: *E. coli* <1,000 /gram and *Salmonella* < 3 MPN/4 grams) [MPN= Most Probable Number]

3. Inorganic fertilizers

Inorganic fertilizers are obtained via commercial chemical processes. Although the products are generally not a source of microbial contamination, care should be taken to ensure that microbes are not introduced through contaminated water used to mix the products, or unclean equipment used in applying them.

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