Gardens As a Source of Infectious Disease: Reducing the Risk

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Introduction

The purpose of this publication is to review the risk of infectious disease from gardening in South Florida. Although written primarily as a resource for persons involved in organizing and running a community garden, the topics covered should be of interest to all gardening enthusiasts.

The sources of infection are first briefly stated, followed by a review of the types of infectious agents that can cause disease. While much of the emphasis is on food borne infectious agents that can contaminate home grown produce, reference is also made to pathogens that may be encountered directly during the course of gardening activities. Precautions and practices that can be adopted to minimize the risk of infection from gardening are summarized as a set of guidelines at the end of the document

. In many instances those at greatest risk are persons with an impaired immune response, due either to disease (e.g. AIDS, diabetes or alcoholism), chemotherapy, surgery (e.g. splenectomy) or age. For all however, certain precautions are warranted when gardening, so that what should be a pleasurable activity is not a source of discomfort or distress.

The Principal Sources of Infection Present in the Garden

Soil Naturally occurring soil dwelling microbes including bacteria (Clostridia and Bacillus species), as well as various saprophytic bacteria (Listeria), free living Protozoa (e.g. *Acanthamoeba spp*.) and fungi (causing mycetoma), are all documented as causes of illness in humans. Other fungal pathogens (e.g. *Histoplasma capsulatum* and *Blastomycoses dermatitidis)* have also been recovered from soil. Soil can also be a source of infection due to contamination with pathogens present in the urine or stools of either wild or domesticated animals. In such instances the risk of infection will depend on both the resilience of the pathogen and continuing contamination of the site.

Plants. Plants can be a source of infection due to direct inoculation through spines or prickles (as with Sporotrichosis), or ingestion of edible parts contaminated with organisms present in soil or manure. In addition certain organisms capable of causing illness can proliferate during the decomposition of plant material, including composting under certain conditions.

Animal Waste. Infectious organisms may be present in animal by products (e.g. bone and blood meal), or waste (urine and feces) that are used to improve soil fertility. As well as the deliberate introduction of pathogens through the use of farm animal waste, the stools and urine of both pets and wildlife (including birds) can be a problem. Diseases of this type, where there is direct spread from animal to humans are termed zoonoses. The dangers posed by zoonotic pathogens present in raw manure can be considerably lessened if it is correctly composted before use.

Vector Borne Diseases. A mechanical vector is an animal involved in the passive transfer of a pathogen through prior contact with infective material, such as garbage, animal carcasses, or fecal material. Such vectors are usually arthropods (i.e. flies, cockroaches or beetles) or birds. In some instances a vector is a requisite part of the pathogen/parasite life cycle (developmental stages occur), and is referred to as an obligatory or biologic vector. This is the case with mosquito borne diseases such as malaria and certain viral diseases such as St. Louis or Eastern Equine Encephalitis..

Animal Manure and Garden Compost as Sources for Human Disease

Interest in the use of compost as a means of recycling plant and animal wastes is increasing. The use of compost as a soil amendment improves both soil structure and to a lesser extent nutrient content. On a global scale composting could help reduce the amount of energy expended in fixing

atmospheric nitrogen for use as a chemical fertilizer[1]. This in turn would help alleviate the problems caused by run-off of excess inorganic nitrate fertilizer into lakes, rivers and estuaries. Since the disposal of manure has become a major challenge for modern intensive animal production, recycling such waste as compost would seem a natural solution.

However commendable this approach may be, widespread use of composting, if not correctly managed, has the potential of posing a definite public health problem. Most of the concern is associated with the use of animal wastes, particularly manure, and the presence of pathogens capable of infecting humans. Infection can occur not only as a result of tainted food crops, but also the run off from improperly maintained compost piles contaminating water sources used for recreation, drinking and crop irrigation. A 1997 preliminary report for the National Advisory Committee on Microbiologic Criteria for Foods[2] stated that "the adequacy of existing methods and regulations governing the composting of manures for agriculture need to be reviewed". In the U.K. the Institute of Food Science and Technology issued a similar warning regarding the use of animal manure in 2001[3]. There is unfortunately insufficient data on the survival of many of the pathogenic organisms found in manure (either raw or composted) used to grow crops.

Whilst composting for a backyard or community garden does not entail the problems of scale that face agricultural operations, there still remain health related matters that need to be addressed. These potential risks concern both the type of material used for composting, as well as the composting process itself. There is the initial risk from direct contact with manure when it is moved, and the subsequent risk of indirect exposure from run off if the pile is exposed to rain. Insects, birds and rodents can also spread pathogens present in fresh manure to other parts of the garden site and surrounding areas. The use of manure in a home garden/community garden setting cannot be recommended, and the reader is directed to the resources listed at the end of this publication for information on composting in the home garden[4].

The potential threat of food borne disease.

An increase in the frequency of food borne illness during summer has in part been ascribed to the greater consumption of fresh produce. The incidence of fruit and vegetables acting as vehicles for spreading food borne pathogens is rising[5]. For the period 1993 -1997 fresh fruits and vegetables accounted for 2.5 - 3.0% of all reported outbreaks of food poisoning in the U.S., and surprisingly this was more than reported for beef or poultry in most of those same years[6]. The total number of cases of food born disease that can be attributed to known pathogens has almost certainly been grossly under reported in the past, and is now estimated at about 14 million per year[7]. Up to two thirds of these cases involve gastrointestinal disease due to Norwalk type viruses, which are solely associated with human fecal contamination, and would not be of concern when dealing with animal manure. This still leaves a large number of cases attributable to infection with zoonotic bacteria or parasites, and a substantial number of these pathogens are found in animal waste.

The fact that fresh produce has been associated with cases of food borne illness should in no way dissuade gardeners from growing a range of vegetables, or prepare there own compost. Vegetables are too important an item in our diet not to be the focal point of any community garden, and composting a cost effective and beneficial means of improving soil fertility. Being aware of the potential problems and following the recommendations below, as well as those in the resources cited

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1 Socolow, R.H. Proc.Nat.Acad.Sci. USA **96** 6001-6008

2 Tauxe, R.V. *et al* J.Food.Protect. **60** 1400-1408

3 IFST Current Hot Topics: Organic Foods (www.ifst.org/hottop24)

4 See for instance Fitzpatrick, G.E. & Duke, E.R. Proc. Fla. State Hort. Soc. **107** 385-387

5 Beuchat, L.R. & Ryu, J-R. Emerg.Inf.Dis **3** 459-465

6 MMWR **49**/No. SS-1, 27-31.

7 Mead, P.S. et al Emerg.Infect..Dis. **5**, 607-625

at the end of this document, will help ensure safe garden produce.

Non-Food Borne Transmission of Disease

Apart from the presence of pathogens on fresh garden produce, disease transmission in the garden can involve direct infection from soil. This can be orally as a result of inadvertent transfer through soiled hands, or via the skin as a result of abrasion or more traumatic wounds. Puncture wounds from plant spines, prickles and thorns can introduce pathogens. Certain organic products used as growing media for plants, i.e. sphagnum moss, can harbor disease-causing organisms.

There is also a risk of disease transmission through various arthropod vectors, in particular mosquitoes, and to a lesser extent biting flies, ticks and fleas. Scratches and bites from both domesticated and wild animals encountered in the garden can be a source of infection.

The Principal Groups of Organisms that Cause Disease

Before discussing specific health risks, some general background information on the types of pathogens involved will be presented:

Bacteria These are unicellular microorganisms that lack a central, membrane bound cell nucleus, chromatin material being dispersed (termed prokaryotic). The "naked" cell (protoplast) is enclosed in a rigid cell wall. Bacteria can be roughly differentiated on the basis of morphology and staining properties, but exact identification is based on biochemical, serological and molecular properties. Some soil inhabiting bacteria can form extremely resilient spores, whilst elevated temperatures can destroy many of those that cause gastrointestinal disease.

Protozoa As with bacteria, protozoa are microscopic, unicellular organisms. However they possess many organizational features associated with animal cells, in particular the characteristic nucleus of a eukaryotic cell. There are about 66,000 known species of protozoa, of which about 10,000 are parasites. Amongst diseases caused by protozoan parasites are malaria, sleeping sickness, oriental sore and various gastrointestinal infections. It is this latter type of infection, spread through fecal contamination, which is of principal concern to those involved in gardening. Some of the species causing such illness can form highly resistant cysts that are difficult to destroy. Protozoan parasites such as *Giardia* and *Cryptosporidium* have only recently been recognized as significant causes of gastrointestinal disease. Currently, attention is being focused on establishing the pathogenic potential for humans of several gut dwelling microsporidian protozoa, found in various animal species.

Helminths These are simple multicellular organisms composed of two Phyla: the Platyhelminthes (flat worms and tapeworms) and the Aschelminthes (round worms or nematodes). Some of these parasites have complex life cycles involving two or more hosts, and/or an extensive migratory phase within the host. Whilst these worms are important causes of disease worldwide, for the purposes of this publication we are solely interested in various roundworms that normally occur in the gastrointestinal tract. The eggs produced by these parasites are passed in the stools, and infection occurs through ingestion of contaminated food or water, or poor hygiene after contact with contaminated soil or water. The eggs of some nematode parasites can be very difficult to destroy, and remain viable in the soil for at least 12 months.

Fungi The more than 100,000 known fungi constitute a separate kingdom and whilst possessing the characteristics of a plant cell (defined cell nucleus, mitochondria and a rigid cell wall) do not possess chloroplasts and are therefore incapable of photosynthesis. For most fungi the cell wall is composed of chitin like polysaccharides rather than cellulose as found in plants. Fungi exist as either unicellular yeast cells or filamentous multicellular hyphae, and produce spores by both asexual and sexual processes. Whilst fungi can act as pathogens, they are more likely to be an

indirect cause of illness for those gardening, as a result of inhaling released toxic or allergenic compounds.

Viruses There are no known viral pathogens infective to humans that are transmitted through plant or animal waste, though where night soil is used there is a definite risk from viruses present in human feces (e.g. rotaviruses and Hepatitis A). There are viral diseases that are vectored by mosquitoes that can breed in South Florida yards, in particular St. Louis Encephalitis (SLE). The hantavirus is present in dust contaminated with dried rodent droppings or urine and causes a rare, but frequently fatal pulmonary syndrome.

The infectious agent responsible for bovine spongiform encephalopathy (BSE, so called "mad cow disease"), a prion, could theoretically be present in animal bye products such as bone meal, though this is normally steamed[8] before use as a soil amendment[9].

Bacterial Pathogens Present in Animal Waste Potential bacterial pathogens that could be encountered during gardening are presented in Table 1, with an emphasis on those present in animal waste.

Escherichia coli The Escherichia are small motile rod shaped bacteria (bacilli), which occur as part of the normal gut flora of most mammals. There are however certain strains capable of producing potent toxins, particularly the enterohemorrhagic strain O157:H7, infection with which causes a severe bloody diarrhea with cramps. In susceptible individuals, especially children under age 5, serious life threatening complications can occur (hemolytic-uremic syndrome, HUS, and thrombocytopenic purpura, TCP), HUS being the leading cause of acute kidney failure in young children. The number of persons infected with strain O157:H7 in the US is estimated to be about 75,000 annually[6].

Ruminants, in particular cattle, appear well adapted as reservoir hosts and the organism is shed in feces, particularly after calves are weaned. Since a low dose is capable of producing disease in humans, it is important to ensure complete destruction during the composting process. Extended exposure to temperatures in excess of 140EF are required in order to ensure effective killing. There were no E.coli O157:H7 detected after 3 days at 140EF using an artificial bench scale composting system[10], though conditions may not reflect those in an actual compost pile[11]. The organism can remain viable for at least 2-3 months in aerated bovine manure[12], a good reason to first compost thoroughly before use, whilst an aerated pile of ovine feces was positive after 4 months. Survival appears to be greatly lessened if the manure becomes desiccated.

At least one out break of *E. coli* O157:H7 has been traced to vegetables grown in a home garden where contaminated cow manure was used.[13] The droppings of wild birds have been found to contain O157:H7 and other food born pathogens, and it is believed that these infections are contracted as a result of birds feeding in areas where fresh manure was present. This is another reason not to spread raw manure, particular in areas frequented by birds such as gulls.

Salmonella This genus is also made up of motile, rod shaped, enteric bacteria. The most widely known of these bacilli is *Salmonella* serotype Typhi, responsible for typhoid fever and restricted to humans. None-typhoid strains of *Salmonella* (e.g. serotype Typhimurium) are found widely in a

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8 Destruction of prions requires steam sterilizing at 132EC for 4.5 hs (Office of Health Safety, CDC)

9 The use of steamed bone meal in the U.S. is not seen as hazardous by the Centers for Disease Control (person. comm.) and is still recommended by the Royal National Rose Society (U.K.). K. Grapes (person. comm.).

10 Lung, A.J. *et al* J.Food.Protect. **64** 1309-1314

11 Droffner, M.L. & Brinton, W.F. Zentralbl.Hyg.Umweltmed. **197** 387-397

12 Kudva, I.T. *et al* Appl.Environ.Micriol. **64** 3166-3174

13 Cieslak, P.R.. *et al* Lancet **342**, 8867

variety of domestic and wild animals, and up to 50% of a herd or flock can be infected under intensive agricultural practices. Dogs and cats can serve as carriers, as well as many cold-blooded animals. Recent survey data reveals serotypes associated with reptiles to account for an increasing number of human cases of enteric disease. From 30-100% of lizards, snakes, and to a lesser extent certain amphibians are carriers of *Salmonella,* and will intermittently shed bacteria.

Most infections *(Salmonella* serotype Enteriditis) are associated with poultry products, particularly the consumption of under cooked eggs. Since this a relatively mild disease it probably goes undiagnosed in most instances; the number of reported cases for 1998 was almost 44,000[14], but the total number of cases annually has been estimated at almost 1.5 million in the US[6]. Salmonella isolates have been found to survive for up to 6 months in untreated cattle manure, and up to 21 days if composted.[15] In composted chicken manure a 90% reduction in the number of Salmonella occurred in 2 days, and this was correlated with an increase in the concentration of free ammonia in the compost. Bovine manure does not produce such high levels of ammonia on composting.

Campylobacter jejuni The Campylobacter are slender, spirally curved, motile rods, and form part of the commensal gut flora of numerous animal species. *C. jejuni* is estimated to cause 2.5 million cases of gastrointestinal illnesses annually in the U.S.[6], ranging from mild enteritis to severe dysentery. Previous infection with Campylobacter has been associated with about 30% of all cases of Guillain-Barré syndrome[16], a comparatively rare but severe neurological disorder that involves the peripheral nervous system. Most cases of campylobacteriosis are due to the consumption of under cooked poultry. Fecal spread is possible since the organism is present in both cattle (especially young animals) and poultry manure. The number of organisms required to produce disease is high, and survival outside the host is poor[17], therefore it should not pose a problem in adequately composted manure. *C. jejuni* has been found in wild animals (especially birds) and on the exoskeleton of insects, hence providing a potential reservoir for the contamination of water and uncooked foodstuffs.

Listeria monocytogenes These are small short rod shaped bacteria, and unlike the above organisms, are found naturally as saprophytes on decaying plant matter, as well as in soil and manure. There is evidence that the at least some of the strains recovered from plant debris and soil are not pathogenic to humans[4], and that environmental triggers associated with decaying plant material suppress virulence[18]. Listeriosis presents a range of symptoms, from a mild influenza like illness to a severe life threatening form of meningitis, with 2500 cases estimated annually for the US according to the CDC[3]. The more severe course of the disease is much more likely in the elderly, those with an impaired immune system and the very young. In neonates there is up to 90% mortality, whilst AIDS patients are 300x more likely to develop symptoms if exposed to infection.

A link between animal waste and raw vegetables as vehicles for infection with Listeria was made in the early 1980's[19] in an outbreak involving cole slaw made from cabbage that had been grown with manure from infected sheep. More resistant to heat than other non-spore forming food borne bacteria, Listeria has been found to survive in food scrap compost for short periods at temperatures up to 173EF, well above the temperature of most compost piles[20]

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14 MMWR **47**/No. 53, 79

15 Forshell. L.P. & Eskesdo, I. Zentralbl.Veterinarmed. **40** 654 - 658

16 Allos, B.M. Clin.Inf.Dis. **32** 1201-1206

17 Altekruse, S.F. *et al* Emerg.Inf.Dis **5** 28-35

18 Brehm, K. *et al* J.Bacteriol. **181** 5024-5032

19 Schlech, W.F. *et al* N.Eng.J.Med. 308 203-206

20 Droffner, M.L. & Brinton, W.F. Zentralbl.Hyg.Umweltmed. **199** 51-59

Organism	Source	Survival	Human Disease
Salmonella (non-typhoid strains)	Cattle, poultry, dogs, wild birds and reptiles.	Extended exposure to ™140EF required to kill organism.	Usually mild gastroenteritis within 6- 48h
Escherichia coli 0157:H7	Ruminants, especially cattle	Up to 70 days in raw manure	Bloody diarrhea severe cramps HUS and TPC
Brucella spp.	Urine: cattle, sheep, pigs, goats, dogs	2½mos. in moist soil, rapidly killed in sun	Symptoms, from days to months. Brucellosis can be protracted and extremely debilitating.
Campylobacter jejuni	Stools: poultry, wild birds, sheep, cattle, pigs	Rapidly killed by heat, drying and freezing	Mild to severe (bloody) diarrhea
Listeria monocytogenes	Soil, manure, food scraps.	Saprophyte on vegetation - can survive in food compost.	Mild flu-like to severe meningitis, bacteremia
Bacillus cereus	Soil, seed sprouts, prepared foods	Highly resistant spores	Mild gastroenteritis
Rhodococcus equi	Horse manure, particularly foals, soil.	Found naturally in soil	Severe pneumonia if immune system defective.
Leptospira interrogans	Urine of various wild animals, especially rodents	Long term survival in water and moist soil	Usually mild, but complications can be serious (Weil's Disease).
Yersinia enterocolitica	Various wild animals as well as dogs and pigs. Pork products.	Survival in soil or manure not known.	Gastroenteritis.

Table 1 Bacterial Pathogens Associated with Animal Waste

Unlike most other organisms associated with food born disease, Listeria can survive and even multiply at much lower temperatures[21]. There is only sparse information available on survival in animal manure or compost. One study reported survival in fresh cow manure for at least 3 weeks and found *L. monocytogenes* after 3 months on radishes grown in artificially contaminated soil[22].

Although some of the remaining bacterial pathogens listed in Table 1, are capable of causing serious disease they are of far less concern as possible contaminants of yard compost:

Bacillus cereus Large, motile, rod shaped, bacteria characterized by the ability to form resistant spores. The numbers of food born infections attributable to *B. cereus* have increased in recent years to an estimated 27,000 annually. For most known outbreaks fresh produce was not implicated, however spores are routinely found in soil samples that could be a source of infection if fresh vegetables are not adequately washed. The presence of *B. cereus* spores on seeds used for growing seed sprouts has been a cause of outbreaks of gastrointestinal disease.[23]

21 Schlech, W.F. Clin.Inf.Dis. **31** 770-775

22 Van Renterghem, B. *et al* J.Appl..Bacteriol. **71** 211-217

23 Taormina, P.J. *et al* Emrerg.Inf.Dis **5** 626-634

Brucella spp. These are small, non-motile coccobacilli found in various wild and domesticated animals, and can be the cause of serious disease in humans. Brucellosis is a reportable disease through out the US, however the incidence of human infection in this country is very low. Most reported cases result from the consumption of none pasteurized dairy products. The organism can be found in various bodily fluids and in animal manure, the latter having been implicated in at least one disease outbreak.[24] The organism can survive for as long as 10 weeks in moist soil, but is rapidly destroyed on exposure to direct sunlight.

Yersinia enterocolitica This is an ovoid to rod shaped bacterium, and is estimated to cause more than 96,000 cases annually of food borne illness, most of which are contracted through eating pork products. Since this organism is passed in the stools of various wild and domestic animals (including dogs and pigs), it could pose a potential problem if contaminated pig manure were used to grow fresh produce. There is however little known concerning the survival of *Y. enterocolitica* in manure, either fresh or after composting.

The remaining bacterial pathogens in this section whilst present in animal feces are usually not contracted through eating contaminated foodstuffs. Infection is more likely to be through inhaling dried stools in dust, or introduction through existing skin abrasions or via animal or arthropod bites.

Rhodococcus equi This organism transforms between rod and cocci, and is found naturally in soil. It is also commonly found in the stools of domesticated livestock, particularly horses where it is a well documented pathogen of foals. In humans it causes a rare but serious form of pneumonia, and is almost exclusively found in persons with a compromised immune system[25]. The number of bacteria found in soil is particularly high in localities where there are grazing animals. Inhalation from infected horse manure or heavily contaminated soil is the usual mode of infection, however the few cases reported in healthy individuals have been due to contamination of wounds, where it produces cutaneous lesions.

Franciscella tularensis This is a small, nonmotile coccobacillus, and is responsible for a zoonotic disease commonly referred to as tularemia. In humans it is seen as a severe, sometimes fatal illness, and is found in a wide range of wild animals. It is usually associated with rabbits and almost all known human infections involve an animal bite, or that of a tick or deer fly that has fed on an infective host animal. The organism is capable of surviving in dried animal stools, thereby potentially facilitating infection through inhalation of contaminated dust. Incidence of infection has been declining and only 96 cases were reported in 1994, the last year it was on the C.D.C. list of notifiable diseases. In 1996 tularemia was removed from the Florida list of notifiable diseases.

Chlamydia psittaci This nonmotile, coccoidal, intracellular parasite causes a zoonotic disease, psittacosis (also known as ornithosis), of cosmopolitan distribution. The bacterium was first associated with psittacine birds (parrots), but is now known to occur in many other wild and domesticated birds. Infection in humans is due to inhalation of bacteria, either directly from infected birds or those present in stools. Care should be exercised when working with previously undisturbed soil that may be contaminated with bird manure, as could occur on sites where birds have been known to roost. As with tularemia, this is another zoonotic disease that has also declined in incidence, with 48 cases reported in 1998.

Leptospira interrogans This bacterium is a tightly coiled motile rod, a spirochete, and is responsible for a comparatively rare zoonotic disease (Leptospirosis), that can range from a mild fever, to a severe condition sometimes referred to as Weil's disease. In this latter instance symptoms include hepatitis (with associated jaundice), meningitis and kidney involvement with

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[24] Wallach et al., FEMS Immunol.Med..Microbiol. **19** 315-321

[25] Linder, R. Emerg. Infec. Dis. 3 145-153

renal failure being the usual cause of fatalities. Although associated with various wild animals, especially rodents, it also occurs in cats, dogs and domesticated livestock. The bacteria are found in the urine of infected animals; humans contract the disease via mucosal surfaces or skin abrasions. This can involve direct contact with contaminated water (the usual route), soil or vegetation, or indirectly through consumption of foodstuffs exposed to tainted soil or water. The organism is able to survive for weeks if not months in contaminated soil or water.

The risk of disease can be greatly reduced through care over hygiene in handling manure, and paying particular attention to controlling rodents and wearing gloves and appropriate footwear when gardening. Control of rodents is important, not only to prevent direct spread, but also to prevent infecting populations of stray and feral dogs. There has been a recent increase in the numbers of dogs infected with Leptospires Whilst Leptospirosis is no longer a notifiable disease, only 38 cases being reported by the CDC for 1994 the last year for which data is available, it is potentially life threatening.

Thermophilic Actinomyces These are a group of bacilli that thrive at elevated temperatures. They multiply rapidly in compost piles that reach temperatures of more than 60C, but there presence is unrelated to the presence of manure, since they are commonly found in silage pits. Actinomyces produce allergens that can cause various forms of respiratory distress. The elevated temperatures required for proliferation of these bacteria are unlikely to be produced during small scale yard composting.

Protozoan Parasites Present in Animal Feces There are three parasitic protozoa found in animal manure that are of principal concern as potential contaminants of fresh produce.

Giardia duodenalis (syn *G. lamblia*; *G. intestinalis*) The feeding stage (trophozoite) of this flagellate protozoan is found next to the lumenal surface of the small intestine. Trophozoites can transform into a resistant cyst that is then eliminated with the feces. There is no intermediate host, and no resting stage, so the cysts are immediately infective upon being ingested by a new host. Disease symptoms include diarrhea (stools are particularly malodorous), steatorrhea (greasy stools), nausea, bloating, and in long-term infections malabsorption and weakness.

Based on surveillance data, the CDC has estimated 2 million cases of infection with *G. duodenalis* annually for the U.S. Whilst 90% of these cases are probably water borne, that still leaves 200,000 potential cases of food borne giardiasis per year. In Florida alone there are about 2000 cases per year. *Giardia sp.* are found widely in vertebrate hosts, though *G. duodenalis* is the only species recognized as parasitizing mammals, where it is found in dogs, cats, various herbivores and ruminants. Infection rates of up to 100% have been found in dairy calves, whilst infection rates for dogs and cats have seen a steady increase. Recently, genetically distinct sub groups of the parasite have been recognized, some of which are associated with a single animal host, whilst others are found in more than one host. It would appear therefore, that whilst not all animal infections with *G. duodenalis* are transmissible to humans, there still exists a substantial animal reservoir of infection[26]. With further genetic sub-typing of *G. duodenalis* it will be possible to ascertain which animal reservoirs pose the greatest risk for human infection.

Care should be taken to keep dogs away from garden areas where cow manure is present, since they could potentially contract giardiasis and contaminate fresh sites with cysts. There is also a need to prevent contamination of the site through rainwater washing parasite cysts from the manure or compost pile onto the surrounding ground. This is particularly important if well water is being used to irrigate the garden, since contaminated water supplies have been implicated in most outbreaks of giardiasis. The cysts are resistant to drying, chlorination and temperature extremes, are able to survive for months in water, and are relatively persistent during treatment of wastewater[27]. There

[26] Thompson, R..C.A. Int. J. Parasitol. **30** 1259-1267

[27] Chauret, C. *et al* Can J. Microbiol. **45** 257-262

is little information concerning their survival in manure or compost; a survival of at least 16 days was noted in pig manure slurry[28], less than for water. Whilst the potential contamination of garden produce with Giardia, through manure/compost or contaminated well water is possible, the exact nature of the risk is unknown. It is however worth noting that ingestion of as few as 10-25 cysts has been documented to produce disease in humans[29].

Organism	**Animal Source**	**Survival**	**Human Disease**
Protozoa			
Giardia duodenalis	Widespread in many vertebrate hosts, especially ruminants, dogs and cats.	Long term survival of cysts, resistant to drying and temperature extremes	Diarrhea, cramps, flatulence nausea, steatorrhea; can be protracted and debilitating.
Cryptosporidium parvum	Cattle of primary importance	At least 6 months in manure - susceptible to drying.	Self limiting gastroenteritis - Protracted in susceptible individuals
Toxoplasma gondii	Cat feces, undercooked meat	Cysts survive at least 1 year in a variety of soils	Often asymptomatic, but can be serious complications in susceptible individuals.
Cyclospora cayatensis	Existence of animal reservoir has not been established as yet.	Long term survival in water	Watery, protracted diarrhea especially debilitating in susceptible individuals.
Helminth			
Ascaris suum	Pig feces	At least 8 weeks in moist pig feces	Pnemonitis, gastric symptoms
Toxacara spp.	Dog (*T. canis*) and cat (*T. cati*) feces	A year during composting, 4 years in garden soil.	Visceral larva migrans, usually in children.

Table 2. ***Protozoan and Helminth Parasites of Possible Concern to Gardeners***

Cryptosporidium parvum The Cryptosporidia are found in a wide range of animals, from reptiles to birds and mammals, including humans. In man, *Crptosporidium* is an intracellular parasite of the epithelial absorptive cells of the small intestine. Infection occurs through the ingestion of oocysts, which rupture to release four sporozoites. These become motile and attach to and invade the epithelial cells of the small intestine, destroying the microvilli in the process. Within the host cell, the parasite is contained in a parasitophagous vesicle (a fact which complicates development of successful chemotherapy), where it divides to produce merozoites that in turn invade further epithelial cells. Eventually the merozoites differentiate into male and female gamonts, these then fuse to form a zygote that encysts to form an oocyst, and this is then passed out with the stools. The cysts are immediately infective once voided, there being no resting phase. Ingestion of very few parasites can produce disease (median infective dose 132 oocysts[30]), though this is probably dependent on the isolate. In immunocompetent individuals infection is a self- limiting gastroenteritis lasting at most 2-3 weeks, whereas in those with an impaired immune system it can produce a severe, persistent form of watery diarrhea.

Most documented cases of disease are associated with contaminated water[31] (used for drinking,

[28] Deng, M.Y. & Cliver, D.O. Appl. Environ. Microbiol. **58** 2368-2374

[29] Clark, D.P. Clin. Microbiol. Rev. **5** 93-100

[30] DuPont, H.L. *et al* N.Eng.J.Med. **332** 855-859

[31] In the largest U.S. outbreak of a water borne disease, cryptosporidiosis affected 25% (403,000) of the total population of Milwaukee in 1993 (MacKenzie, W.R. *et al* N.Engl.J.Med. **331** 161-167).

food preparation or recreation), the CDC having estimated 300,000 cases per year. Of these 30,000 are due to food borne infections, and many of these probably involve food exposed to contaminated water. Consumption of fresh produce has been linked to disease outbreaks[32], however there is no evidence that this involved the use of compost or raw manure. Since the parasite is of ubiquitous occurrence in cattle[33], a potential risk exists if cattle manure is used as a soil amendment. Young calves shed especially large numbers of oocysts; the numbers declining rapidly by the time the animals are 4 weeks old.

Several genotypes of *C. parvum* have been recognized, with two regarded as responsible for human disease: the most prevalent is recovered only from humans (anthroponotic), whilst a zoonotic genotype occurs that involves domestic livestock including cattle. However in addition to these two genotypes, there have been reports of the *C. parvum* dog genotype and two other species (*C. felis* in cats and *C. meleagradis* in birds) infecting AIDS patients[34]. More recent surveys have found evidence of all three *C. parvum* genotypes, as well as the two other above species infecting children who were HIV negative[35]. At present therefore, the zoonotic component of cryptosporidiosis is not fully understood, however it would seem to involve cattle, cats, dogs and possibly birds.

Survival of Cryptosporidia oocysts in either raw manure or compost has received scant attention; laboratory studies have found survival for at least 6 months at 20EC, with loss of infectivity noted on slowly raising the temperature to 55EC. Desiccation is also extremely lethal, with no infective organism found after drying contaminated calf feces for 4 hours[36]. Cryptosporidiosis has been a reportable disease in Florida since 1992, and since that time the number of cases has noticeably increased, with most reports coming from Miami-Dade, Broward and Palm Beach counties.

Toxoplasma gondii Unlike the protozoan parasites discussed above *T. gondii,* the etiologic agent of toxoplasmosis, has a life cycle involving two sets of hosts. The definitive (sexual stage) occurs in felines, including the domestic cat, whilst the asexual stage occurs as a tissue parasite in a wide variety of mammalian intermediate hosts including humans. In cats, Toxoplasma parasitize epithelial cells of the small intestine, eventually forming gametocytes which after fusing to produce oocysts, pass out with the stools. Large numbers of oocysts are voided with the feces for up to 2 weeks after which none are present. Once outside it takes 4-5 days for the oocyst to sporulate (become infective), after which it is infective to other cats and to intermediate hosts, including man.

In the intermediate host the asexual part of the life cycle then commences. The oocyst wall is digested in the small intestine and the released parasites penetrate the gut wall, enter the bloodstream, and are spread throughout the body. At this time they are able to infect virtually all host cell types, but particularly muscle and nerve cells. These tissue stages are referred to as trophozoites, and are of two types: rapidly multiplying tachyzoites, which spread the infection, and slower reproducing bradyzoites that form tissue cysts. These latter cysts are infective to cats on eating infected prey animals, or raw or undercooked meat.

Infection in humans can occur as a result of consuming tissue cysts in undercooked meat, or from food or water contaminated with oocysts from cat feces. In a healthy person the disease is usually asymptomatic, at most producing flu like symptoms. However in those with an impaired immune system, infection can be far more serious. Toxoplasmosis has been found in 75% of all terminal AIDS patients[37], with involvement of the central nervous system (encephalitis), as well as ocular and respiratory system complications. One other serious complication, congenitally acquired toxoplasmosis, occurs if infection is acquired during pregnancy. Trans-placental passage of the

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32 Nichols, G.L. Brit.Med.Bull. **55** 209-235

33 Casemore, D.P. *et al* In *Cryptosporidium* and Cryptosporidiosis. R. Fayer, Ed. : 65 - 92. CRC Press, Boca Raton, FL.

34 Morgan, U.M. *et al* J.Clin.Microbiol. **38** 1180-1183

35 Xiao, L. *et al* J.Inf.Dis. **183** 492-497

36 Fayer, R. *et al* Int.J.Parasitol. **30** 1305-1322

37 Welch, K. *et al* AIDS Patient Care STDS **12** 125-129

parasite is more likely during the latter half of pregnancy, at which time damage to the fetus is less profound than if exposure occurs during the first trimester. Infection can cause intrauterine death, severe disease in the neonate, and a range of developmental problems as the infant ages if the infection goes undiagnosed.

The CDC has estimated that there are 225,000 cases annually of toxoplasmosis, of which 12,100 develop chronic symptoms, and 50% are food-borne[3]. Most food borne cases involve consumption of undercooked meat, however more recently contamination of foodstuffs with oocysts has been implicated. A survey of toxoplasmosis amongst pregnant women found that whilst undercooked meat was still the primary risk, contaminated soil was also an important source of infection[38]. Contact with cats *per se* was not seen as a risk factor since they pass oocysts for a comparatively short period. However soil that is contaminated by oocysts from infected cat feces could be a potential problem. Cysts have been found to survive for at least one year in different sites (Costa Rica and Kansas), regardless of whether the soil was moist, dry or shaded.[39] The intentional use of cat feces for composting should be avoided, and measures taken to exclude stray and feral cats from the garden site. Cats that are kept indoors and do not consume prey animals or raw meat pose a minimal risk of spreading toxoplasmosis. Toxoplasmosis has been a reportable disease in Florida since 1964.

Other Zoonotic Protozoan Parasites Spread of the remaining zoonotic protozoan parasites through stool contamination of garden produce is not known. Various Microsporidia spp. have recently been identified in immunologically compromised individuals, particularly AIDS patients, as responsible for diarrhea, malabsorption and, depending on the species, dissemination to other organs. Some of these parasites such as *Encephalitozoon intestinalis* have been found in dog and livestock feces and are believed to occur normally in various wild animals. It is not known however to what extent dispersal in humans involves food and/or water, or the role of animals as reservoir hosts. The limited information available has demonstrated long-term survival of the spore stage in the external environment.

Balantidium coli is a ciliated protozoan parasite found in the lumen of the large intestine and is contracted through ingestion of cysts present in water or fresh food. It can cause an ulcerative colitis in those susceptible to infection, but is usually asymptomatic in healthy individuals. Pigs are the most important animal reservoir, infective cysts being passed in their feces.

Cyclospora cayatensis The *Cyclospora* spp are grouped with the *Toxoplasma* and *Cryptosporidia*, all being in the Protozoan Phylum Apicomplexa, and are considered to be most closely related to the *Eimeria*, important parasites of poultry and livestock. *C. cayatensis* causes watery, often protracted diarrhea, nausea and anorexia and is particularly serious for persons with an impaired immune response. There have been a number of outbreaks associated with fresh fruits and produce, with a notable incident involving imported raspberries. There is one report that suggests a link between parasite acquisition and soil and gardening[40]. Unfortunately the mode of transmission of Cyclospora is not fully understood, efforts to establish animal reservoir hosts having produced mixed results, with unconfirmed reports of the parasite being recovered from dogs, chickens and ducks. An extensive study of livestock and other domesticated animals in Haiti, where human infection with Cyclospora is endemic, failed to find oocysts in stool samples from any of these animals[41]. This suggests that if zoonotic spread of Cyclospora is occuring, it probably does not involve domestic animals, and manure from such sources would not be a source of human infection.

Helminth Parasites Dispersed in Animal Feces The two zoonotic helminth parasites that are

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38 .Cook, A.J. *et al* Brit.Med.J. **321** 142-147

39 Frenkel, J. K. *et al* Am.J.Trop.Med.Hyg. **24** 439-434

40 Sterling, C.R. & Ortega, Y.R. Emerg.Inf.Dis **5** 48-53

41 Eberhard, M.L. *et al* J.Parasitol. **85** 562-563

most likely to be encountered as a result of gardening are Ascaris *suum* and *Toxacara spp*. The spread of the former is more likely to involve the food borne route, whilst infection with the latter usually involves direct contact with contaminated soil.

Ascaris suum This is a nematode parasite (roundworm) normally found in the small intestine of pigs. The adult worms produce eggs that are passed with the feces. After 2-3 weeks when they have embryonated, they are capable of infecting a suitable host on ingestion. The eggs hatch in the small intestine, the released larval worms penetrating the wall of the duodenum, passing via the circulatory system to the liver and heart, and then to the lungs. Here the larvae break out into the alveoli where they molt, then migrate through the air passages to the trachea and thus to the oesophagus where they are swallowed. They finally mature in the small intestine as adult, egg producing worms. In humans full migration is often not completed and depending on the initial dose the only symptom may be pneumonitis. Complete migration can occur however, with adult worms capable of causing intestinal obstruction in some instances.

Survival of *A. suum* eggs was observed for at least 2-4 weeks in slurried pig manure allowed to dry in direct sun, whereas 90% were still viable after 8 weeks if the slurry remained moist and away from direct sun[42]. *Ascaris lumbricoides* is the ascarid found normally in humans, and dissemination is through fecal contamination of food or water. (e.g. night soil or improperly treated sewage).

Toxacara spp These roundworms are found in the small intestine of domestic dogs (*T. canis*) and cats (*T. cati*), where they undergo a migratory phase similar to that described for Ascaris. In humans, the migrating larvae never reach the gut but migrate through various tissues (including the liver, lungs, heart and kidneys), a condition known as visceral larva migrans (VLM). This aberrant migration can cause hepatomegaly, myocarditis, nephritis and pulmonary inflammation. Serious ocular complications can occur when larvae migrate across the retina, with blindness being a common outcome. These sequelae are far more common in young children, and are usually due to *T. canis*. Incomplete migration also occurs in dogs older than 10 weeks. However in pregnant dogs, development of the parasite resumes with subsequent transplacental infection of the pups in utero, and viable egg producing worms in the lactating dam.

Toxacara are ubiquitous, with parasite eggs being recovered from the soil in up to 11% of all backyards sampled in one study, whilst in a separate investigation of a mixed population of cats (strays and house cats) *T. cati* eggs were found in 3.9% of all fecal samples[43]. Prompt removal of cat and dog feces is essential, since parasite ova can be spread by coprophagous insects, especially flies, or run off after heavy rain. Once more it should be evident that dog and cat feces should on no account be used for compost. *Toxacara* ova have been found to survive for a year during composting, and up to 4 years in garden soil.[44]

In view of the high rate of infection in dogs, those with gardens in locations where stray and feral animals are common should pay particular attention to excluding them from the garden site. Although infection through consumption of contaminated produce is possible, exposure of children to infection through contact with soil is of more concern. VLM is primarily seen in young children. Supervise children, making sure that they wash their hands as soon as gardening activities cease and be alert for any showing signs of pica. If the garden has a sandpit, keep it covered when not in use since it will act as a large litter box for neighborhood cats. This will also help to prevent contamination with *Toxoplasma* cysts (see above). Do not use this sand as a soil amendment.

Baylisascaris procyonis This round worm is found in raccoons, and is the cause of an especially severe neurological form of VLM, especially in young children[45]. The eggs are able to survive in

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42 Gaasenbeek, C.P. & Borgsteede, F.H. Vet. Parasitol. **75** 227-234

43 Hill, S.L. *et al* J.Am.Vet.Med.Assoc. **216** 687-692

44 Referenced in Int.J.Parasitol. **30** 1379-1393

45 Park, S.Y. *et al* Pediatrics **106** e56

moist soil for years, and in addition are known to be infective to other species including rabbits, guinea pigs and dogs. The parasite is found throughout the U.S and Canada, most frequently in the mid-west and western states, and high numbers of eggs are associated with communal areas where raccoons defecate. These so called latrines, in an urban setting, can be a raised wood deck, woodpile or a large tree stump.

Creeping Eruption As well as VLM, a cutaneous larval migrans (CLM) is caused by the aberrant infection of humans with dog or cat hookworms. Of the four species of hookworm present in Florida, *Ancylostoma braziliense* is found in both dogs and cats, and is the most common cause of CLM. Infective (third stage) larvae, present in dog feces, penetrate the skin causing a serpigenous (spreading) lesion and severe pruritus, as the larvae wander through subcutaneous tissue and eventually die. *Ancylostoma canium*, which is the most frequently found hookworm in dogs, can in very rare instances migrate to deeper tissues and cause symptoms more like those of VLM. Once voided with host animal feces, infective larvae can survive for several days in sandy soil, but are rarely found far from the immediate spot where the animal defecated. *A. canium* can be passed from a lactating bitch to pups by trans mammary passage. As with Toxacara, puppies are a significant source of infection, very large numbers of infective larvae being passed during the first 2-3 weeks of life. Stray and feral animals that have never been treated with appropriate anthelmintics (wormed) pose the greatest threat.

There are no effective chemicals that will rid contaminated soil of any of the above helminth eggs or infective larvae. It is a waste of time and money to apply turf pesticides, and only unnecessarily adds to the potential pollution of surface and ground water supplies. Prompt removal of dog and cat feces will greatly reduce any risk of infection.

Other Food Borne Zoonotic Parasites There are other diseases caused by animal parasites that have been associated with the consumption of fresh produce, however domestic cases have been the result of exposure whilst outside of the U.S. Increasing international travel and trade increase the likelihood that some of these diseases will spread beyond their present borders.

As an example, *Angiostrogylus costariciensis* is a small roundworm parasite of rodents, notably the cotton rat, adult worms being located in the mesenteric artery. It is here that egg laying occurs, the hatched larval worms then penetrating the wall of the small intestine to be subsequently eliminated with the stools. Further development requires the larval worms to be eaten by an intermediate host, usually a veronicellid slug but snails too can be infected. Vegetables become contaminated with infective third stage larvae that are deposited in the mucous secreted by feeding slugs/snails.

Disease outbreaks in humans are usually associated with eating fresh vegetables, and have been reported from various areas of Central and South America, especially Costa Rica and the Yucatan. In humans the eggs and first stage larvae induce severe local inflammatory reactions, leading to the production of granulomatous masses in the intestinal wall, and symptoms that mimic appendicitis (abdominal angiostrongyliasis). Because of this host response, first stage larvae are unable to break out into the gut and the thus humans play no role in spreading the disease, being a dead end host as far as the life cycle is concerned. At present there have been no reports of this disease being contracted within the U.S., however the worm has been recovered from cotton rats in southern states.[46]

Soil Borne Infections

Clostridia There are a number of naturally occurring soil microbes that can cause disease in humans, a well-known example being *Clostridium tetani*, the bacillus responsible for tetanus (lockjaw). In this instance infection is acquired through skin abrasions or cuts, with tetanus symptoms occurring after about 8 days. Whilst the bacterium is readily killed by heat and oxygen,

[46] Control of Communicable Diseases Manual, 17th Edition, J. Chin Ed., American Public Health Association, p.17

it produces an extremely resistant spore that will germinate and divide only under suitable conditions, i.e. low oxygen concentrations (anaerobic). Although cosmopolitan in distribution, *C. tetani* is especially prevalent in warm, humid climates and in soil with a high content of organic matter. The bacterium is found in the gut and feces of a range of animals, and high spore counts are associated with soil that receives regular applications of manure. The heat developed during backyard composting of animal manure will not destroy *C. tetani* spores[47].

The number of U.S. tetanus cases have declined dramatically, particular with the introduction of an effective vaccine in the 1940's, and almost all cases currently reported are found in those who have not been vaccinated. It is currently recommended that after the initial series of vaccinations, booster shots be administered at 10-year intervals[48]. Apart from ensuring that all persons working in a community garden have current vaccinations, gloves should be provided for those handling soil and nobody allowed on site unless they have appropriate footwear. A majority of the tetanus cases that are reported involve puncture wounds resulting from persons stepping on dirty nails. Be particularly careful when preparing a new garden site on land that has stood vacant, particularly in urban areas cleared of derelict buildings, for objects with pointed or sharp edges.

Histotoxic Clostridia are also found in soil and can cause extensive tissue destruction (myonecrosis) as a result of injuries involving crushed limbs or deep muscle wounds. The bacterium most often associated with this condition, *C. perfringens* also causes a mild form of food poisoning usually associated with improperly heated meat dishes.

Fungi Many types of fungi occur naturally in the garden, where they play an important role in the breakdown of organic matter in the soil. Some molds, although not infectious to humans, produce compounds that act as allergens when inhaled. This results in a variety of symptoms in susceptible individuals, including nasal discharge, asthma or pneumonitis. Repeated exposure can cause symptoms to become worse as the individual becomes more sensitized to the fungal allergens.

There are fungi capable of growing in or on the human body, where they cause diseases referred to as mycoses. Histoplasmosis is primarily a disease of the respiratory system caused by inhalation of spores of *Histoplasma capsulatum*. In most people there are no symptoms, whilst in others infection produces a mild flu like illness. Infections can in some cases produce a chronic disease that worsens with time and resembles tuberculosis. In rare cases a disseminated form of the disease can occur, and this is fatal if not treated. Serious complications are more likely in persons with weakened immune systems, and the disease is recognized as a risk factor for AIDS patients. Spores of *H. capsulatum* are found in soils throughout the U.S, particular in those having high nitrogen content. Sites enriched with bird droppings are particularly likely to have elevated numbers of spores, and areas under roosting sites of blackbirds, grackles and pigeons are especially prone to be contaminated. Fresh droppings are not infective, but as they dry out the growth of the fungus already present in the soil is encouraged. Due care needs to be exercised when disturbing soil on any site where birds are known to have roosted for three or more years. Gardening has been listed as a risk activity for contracting histoplasmois by the National Institute for Occupational Health and Safety.[49]

Aspergillosis is primarily a localized pulmonary infection caused by inhalation of fungal spores produced by *Aspergillus spp.* (usually *A. flavus* or *A. fumigatus*) and is usually manifest in those with some underlying lung disorder. In persons with a suppressed immune system, infection can spread to other sites such as the brain and bone. The fungus is widespread in the environment both indoors and outside, but is especially prevalent in decomposing vegetation.

One other fungal disease that has recently become of much greater significance as an opportunistic mycosis is cryptococcosis, caused by the soil fungus *Cryptococcus neoformans*. Infection occurs

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47 Spores survive 15-minute steam sterilizing at 121EC.

48 Epidemiology and Prevention of Vaccine-Preventable Diseases, 6th Edition, p. 57-66. Public Health Foundation, Maryland, 2001.

49 DHHS (NIOSH) Publication No. 97-146 September 1997

through inhalation of spores or yeast cells, with most cases being asymptomatic. In those persons with a compromised immune system (particularly AIDS patients), a serious disseminated form of the disease occurs, usually as a meningoencephalitis. *C. neoformans* like *H. capitulatum* thrives in ageing bird manure, particularly that from pigeons, in sites not exposed to direct sun. However, recent survey data has been unable to establish any clear risk between sites where bird droppings are plentiful and the acquisition of disseminated cryptococcosis[50]. At present it is advisable for anybody at risk for this disease to consult a health professional before working with soil, particularly on a site known to have had a previous resident bird population.

An increasing number of other opportunistic fungi are being implicated as causes of serious complications in immune compromised individuals. Some of these organisms are well known as causes of plant diseases (i.e. Alternaria, Bipolaris and Fusarium), and are of ubiquitous occurrence. Any increased risk of infection with these fungi as a result of gardening has not been established. Although the above mycoses are contracted through inhalation of spores or yeast cells, infection with some fungi is through skin abrasions and cuts. Sporotrichosis, a subcutaneous mycosis caused by *Sporothrix schenckii*, is such a disease and is often associated with handling plants having spines, prickles or thorns. It is usually identified with persons who are debilitated through disease, poor diet, old age or alcoholism. Symptoms of infection are seen within days to weeks as a hard skin nodule, which darkens and erupts to form an ulcer. Involvement of the lymphatic system results in the infection spreading to adjacent sites, where new lesions are formed. The disease may resolve without treatment or on rare occasions become disseminated. Disseminated sporotrichosis is seen in those with a severe underlying immunological deficit, and was typically associated with alcoholics and those receiving immuno-suppressive therapy. It is now recognized as a potential complication of HIV infection[51].

In the U.S the number of cases are few, and it has been referred to in the past as "alcoholic rose-gardeners syndrome", having had an association with middle age, white gardeners with a drinking problem. Rose prickles have been identified as a potential source for infection; a recent survey of prickles recovered from rose plants in Oklahoma revealed the presence of numerous opportunistic fungi (see above) as well as a lesser incidence of *S. shenckii.*[52] Other sources of infection that have been identified include pine needles, as when handling seedling pine trees, and dried sphagnum moss, widely used as a growth medium for plants. Precautions such as wearing long gauntlet style gloves should be taken when garden activities involve handling plants or other items (i.e. baling wire) that could cause cuts or abrasions. Limit skin contact with products such as sphagnum moss by wearing gloves and long sleeved clothing, and avoid working with this material if you have recent skin abrasions.

Free Living Amoebae A number of free-living amoebae have been found worldwide in soil, water and even air samples that are capable of causing disease in humans. One of these, *Naegleria fowleri*, causes a rare but rapidly fatal form of meningoencephalitis (PAM: primary amoebic meningoencephalitis). The majority of cases involve young, active, otherwise healthy individuals, with an immediate history of bathing or swimming in polluted bodies of warm fresh water. Infection occurs through the nasal passages, amoebae penetrating the olfactory neuroepithelium and migrating up the olfactory nerve to the brain. Death occurs 3-7 days after infection. Gardening poses no risk of contracting PAM.

Various *Acanthamoeba sp.* can cause opportunistic infections, including a sight threatening keratitis (particularly in contact lens wearers), and are of ubiquitous occurrence. In individuals who are severely weakened and/or immunocompromised, a disseminated form of acanthamebiasis occurs involving the skin and various internal organs, particularly the brain. Infection is thought to

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50 Hajjeh, R.A. *et al* J.Infect.Dis **179** 449-454

51 Heller, H.M. & Fuhrer, J. AIDS **5** 1243-1246

52 Flournoy, D.J. et al J.Okla.StateMed Assoc. **93** 271-274

usually occur via the respiratory tract, although the spread of amoebae by means of the circulatory system from skin ulcers is also believed to be a factor[53]. One other free-living amoeba, *Balamuthia mandrillaris* also causes encephalitis, though it is observed less frequently than *Acanthamoeba.* Although found in soil, there is as yet no evidence to suggest an increased risk of infection with either *Acanthamoeba* or *Balamuthia* when gardening.

Amebic dysentery is caused by a parasitic amoeba, *Entamoeba histolytica,* and is contracted through food or water contaminated with cysts passed in human feces. There is no animal reservoir and gardening should not increase the risk of infection if due attention is paid to personal hygiene habits.

Hantavirus Pulmonary Syndrome This viral disease is not necessarily soil borne, but is included in this section more for convenience. The virus is most often contracted through inhaling dust that contains dried rodent feces, saliva or urine. Infection is rare but has an overall 30% fatality rate. After an initial 3-5 day period of fever, chills and muscle aches, the cardiopulmonary phase of the disease progresses rapidly with marked pulmonary oedema, death usually being due to respiratory failure.

One case has been reported in Florida (South Dade County, 1994), at which time a new hantavirus was identified (Black Creek Canal Virus) in local cotton rats. Extensive surveillance for evidence of further cases revealed this to be an isolated event, and no further incidents have been reported in Miami-Dade County. However since hantavirus infection is sufficiently serious, and up to 60% of all cotton rats sampled in certain South Dade locations were positive for the virus[54], care should be exercised. Previously undisturbed sites with a known rodent population require special care, particular if dust is present. When clearing an area for use as a community garden, wet down any dust and wear an appropriate protective mask. Be particularly careful if the site includes abandoned structures that need to be cleaned out for future use as storage areas for garden tools and supplies.

Vector Borne Infections

As was mentioned above, mechanical transfer of pathogens by animals, especially insects and birds, can be greatly reduced by covering garden refuse and compost piles, and not spreading raw manure. Apart from the more obvious mechanical vectors, such as filth flies, cockroaches and beetles that are normally associated with dispersing pathogens from contaminated waste, less obvious vectors have been implicated. For instance fruit flies were found capable of transferring *E. coli* from a compost pile containing spoilt fruit, to wounds on uncontaminated fruit where the bacteria then grew exponentially[55].

Mosquitoes These are the most important biologic arthropod vectors in South Florida, and the Culicine mosquito, *Culex nigripalpus* the most significant species for spreading human disease. It is responsible for the transmission of St. Louis Encephalitis (SLE) in South Florida, and would seem set to play a role as a vector of West Nile Virus (WN) as it becomes established in this part of the state. Eastern Encephalitis (EE) is of more concern north of Lake Okeechobee, and involves different mosquito vectors. All of these diseases are due to a group of viruses collectively known as arbor viruses, a term which refers to their mode of transmission (abbreviation of arthropod borne). All of the three above viral diseases are normally found in birds, where they cause no symptoms (SLE) or numerous fatalities (WN). In humans, symptoms can range from a mild flu like illness, to fatal encephalitis. After middle age, the risk of serious complications from SLE increases noticeably. . The disease is not vectored from person to person, since the number of circulating viruses (viremia) is never sufficient to develop in a mosquito after it has taken a blood meal. Transmission to

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53 Brain Pathol. 7 583-598

54 Glass, G.E. et al Am.J.Trop.Med.Hyg. **59** 699-703

55 Janisiewicz, W.J. et al Appl. Environ. Microbiol. **65** 1-5

mosquitoes only occurs from birds and is restricted to a limited period of 1-3 days post infection when the viremia is sufficiently high, after which the virus disappears from the circulating blood.

Cx. nigripalpus is found year round in hammocks and other moist wooded areas and breeds in semi-permanent bodies of water. During the wetter months of the year as humidity levels rise, this species will move out into more open areas, particularly after heavy rain and deposit eggs in areas of temporary standing water. These could be freshly flooded ditches, hollows in the ground, old tires or any receptacle in the yard where water will collect and could be expected to remain for 10-14 days. It is the responsibility of gardeners to minimize potential breeding sites by removing objects favoring the accumulation of standing water. Failure to do so will in many instances violate local ordinances, with violators being subject to fines. In certain counties, such as Miami-Dade, this includes a ban on cisterns designed to collect rainwater for irrigation use.

During a summer drought, gravid female mosquitoes will refrain from laying eggs or feeding, however once there is adequate rainfall, about 2", they will deposit masses of eggs in a suitable site, then take a blood meal to develop further eggs. Periods without significant rain that last for more than 10 days (the incubation period for the SLE virus in *Cx. nigripalpus)*, will increase the infectivity of mosquitoes when taking a blood meal. Under such summer climatic conditions (i.e. a 15 -20 day period of sparse rainfall, followed by a downpour) the chance of being bitten by an infected mosquito is greatly increased. Feeding occurs in the period just after sunrise and before sunset, and it is only the female mosquito that requires a blood meal, in order to produce eggs. Otherwise both male and female insects will feed on nectar and plant secretions. Throughout winter and spring, birds (notably pigeons, mourning doves, blue jays, cardinals and sparrows) predominate as hosts for *Cx. nigripalpus*. However in summer, birds and mammals are of equal importance. .

World wide, mosquitoes are vectors of many other diseases however none, including malaria and dengue, are important at this time in South Florida. There is also no evidence to suggest that mosquitoes or any other arthropod vectors are involved in the spread of HIV 1 or 2 (human immunodeficiency virus).

Ticks and Mites. These are members of a group of arthropods (the Acarina) that also includes spiders, with ticks being divided into soft and hard-bodied types. Depending on the species, development of the tick through nymphal stages to adult can occur on the same host or may involve two or more different types of host. Both types of ticks take blood meals and are capable of vectoring a variety of diseases to both humans and animals, however it is the hard ticks that are of most importance in the US. In South Florida the hard ticks most commonly encountered include the brown dog tick *Rhipicephalus sanguineus*, the American dog tick (*Dermacentor variabilis*) and the blacklegged tick (*Ixodes scapularis*). The brown dog tick rarely attacks human and is not known to vector human disease in Florida, however it is implicated in spreading canine ehrlichiosis.

The American dog tick will attack humans and can spread *Rickettsia rickettsii*, the organism responsible for Rocky Mountain Spotted Fever, as well *Ehrlichia chafeensis*[56] the bacterium responsible for human monocytic ehrlichiosis. Rocky Mountain Spotted Fever occurs most frequently in northern Florida, though it is a potential risk throughout the state. Human ehrlichiosis (a febrile often fatal illness that is difficult to diagnose) has been a notifiable disease in Florida since 1996. However it's distribution in the state is uncertain, most reported cases to date being found in central and north Florida This correlates with the distribution of the principal tick vector *Amblyomma americanum* (lone star tick).

Whilst the American dog tick can be found in overgrown undisturbed urban and rural sites, the blacklegged tick is more restricted to wooded areas. Both of these ticks produce neurotoxins in their saliva that, with prolonged attachment during feeding, can cause tick paralysis. The few cases reported are usually found in young children and are more prevalent in the Rocky Mountain and northwestern states of the US. The black legged tick is the principal vector of *Borrelia burgdorferi*, (the bacterium responsible for Lyme disease) in the eastern US. Disease outbreaks in Florida are far

[56] Walker, D.H. & Dumler, J.S. Emerg.Inf..Dis. **2** 18-29.

fewer than in northeastern states, a fact that could well be due to differences in the ecology of the tick as it pertains to its role as a vector in Florida. For instance in the south, the nymphal stages do not feed on humans, thus transmission of *B. burgdorferi* is restricted to feeding by the adult tick.

Mites are microscopic members of the Acarina, and though most are free living many are found as ecto and endoparasites of both vertebrate and invertebrate hosts. As a group they are not known to be important disease vectors in the US, however they are significant causes of severe dermatitis and produce allergens that can cause pronounced hypersensitivity reactions. *Sarcoptes scabei* causes scabies in humans and mange in various domestic and wild animals. Different races of the scabies mite are found on animals, none of which are able to become established and reproduce on humans. Close contact with an infected animal (i.e. a stray dog) can however cause a transitory infection resulting in urticaria that may last several days. A variety of mites are found on wild animals, including mammals, birds and even insects that can cause temporary severe itching in humans. Bird mites can be particularly troublesome and will migrate from recently abandoned nests to find alternative hosts, including humans. If it is necessary to handle an abandoned bird nest or dead bird wear gloves and keep any contact to a minimum.

Animal Bites and Scratches

Working in a garden can involve unpleasant encounters with animals, and if this results in bites or scratches, the risk of contracting a serious illness. From 12 - 20% of all dog bites become infected, whilst for cats the number is more than double. Although dogs have far more powerful jaws, their teeth are quite blunt compared to the sharp pointed teeth of a cat, which can easily penetrate joint capsules and bone. The oral cavity of all mammals supports a variety of normally commensal bacteria (at least 40 species/ types are present in the dog[57]), so that the mixed microbial nature of an infected bite wound would be expected. Typically 4 or 5 different species of bacteria are isolated from bite wounds, some of which are more commonly encountered than others and can lead to more significant complications. The inquisitive nature of children makes them more likely to approach wild or stray animals and to be at risk[58] if the animal becomes aggressive.

Pasteurella multocida, This coccobacillus is found in the oral cavity of 70 -90% of domestic cats, and is the most frequently encountered species in cat bite infections, being present in more than 50% of all cases investigated. It is also often though less frequently encountered in dog bites. The onset of symptoms is rapid with acute pain, swelling and diffuse redness of the skin being noticeable within 6 hours, all symptoms highly suggestive of *P. multocida*.[59] Complications including wound abscesses, joint diseases, endocarditis, meningitis and bacteremia are most often observed with those having a predisposing illness such as diabetes, cirrhosis of the liver, or a compromised immune systems. A 30% fatality rate is associated with blood infections.

Capnocytophaga canimorsus is a normal part of the microflora of the canine oral cavity, and can also be found in cats. Infection can cause a range of symptoms including fever, cellulitis, endocarditis, meningitis and septicemia. Existing conditions such as alcoholism, diabetes, severe pulmonary disease and splenectomy predispose a person to developing the above symptoms. Whilst a bite or scratch is associated with most infections, the saliva from the lick of an animal can result in infection in a susceptible person.

Cat Scratch Disease. This is sometimes referred to as Bartonellosis and is caused by *Bartonella henslae* one of a group of bacilli that have all adapted to an intracellular existence within the cells of

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57 Smith, P.F. *et al* J.Clin.Pharm.Therapeut. **25** 85-99

58 Glaser, C. *et al* Ped.Rev. 21 219-232

59 Westling, K. *et al* J. Infect. **40** 97-98

various mammalian species. Infection results in fever with localized pain and swelling (lymphadenopathy) sometimes with papule formation. Most cases of CSD resolve without further complications, though up to a quarter can involve ocular, hepatic and cardiac symptoms. Persons with a compromised immune system may develop bacillary angiomatosis (benign tumor like growths composed of blood vessels), bacillary peliosis (purpurea of skin and mucous membranes) and a relapsing bacteremia[60]. From survey data it appears that *B. henslae* is a widespread and persistent parasite of cats, though there are no overt signs of infection, bacteremias being detected for at least 15 months. The disease is spread amongst cats by the cat flea *Ctenocephalides felis*, and this may pose a threat to certain cat owners, especially those with immune deficiencies. Of much greater significance for the spread of *B. henslae* to humans are wounds resulting from cat scratches or bites. It is believed that transmission occurs when cat flea feces, which is known to contain viable bacilli, contaminates the animals claws or teeth[61].

Apart from contamination of wounds with microbes that are a normal part of the microflora/fauna of the oral cavity, there are pathogenic organisms not normally resident in the mouth that can also be introduced by way of an animal bite. Previous reference has been made to diseases such as tularemia and tetanus, both of which can be contracted from animal bites. However by far the most serious infection that can result from an animal bite is rabies.

Rabies. Rabies is rapidly fatal encephalitis caused by a neurotropic rhabdovirus (*Lyssavirus*). Although there have been no human cases contracted within Florida since 1948, rabies is now endemic in the state's wildlife population. Raccoons and foxes form an enzootic cycle that maintains the disease in the wild, and with increasing urbanization encroaching on wildlife habitat, the risk of stray dogs and cats becoming infected increases. This is ample reason to be cautious when in the vicinity of stray animals, particularly if they appear overly aggressive. In contrast, infected wild animals such as raccoons may appear unusually docile. State law mandates that all cats and dogs must have a current rabies vaccination. Any known cases of animal rabies are reported to local health departments and are usually publicized in the local media. Take extra precautions when gardening, if a rabies alert has been issued for your area.

Guidelines to Reduce the Risk of Gardening Related Diseases

From a consideration of the information provided above, the following set of recommendations are presented for reducing the risk of infection from potential human pathogens that could be encountered whilst gardening. This encompasses the risk from time spent in the garden, as well as the subsequent consumption of garden produce. The resources listed at the end of the document should also be consulted for pertinent health related information and relevant safe horticultural procedures

- Do not spread raw manure on the garden.

- Avoid the use of animal manure when composting, particularly in a small home garden compost pile, where temperatures are unlikely to be sufficiently high to

60 Windsor, J.J. Br.J.Biomed.Sci. **58** 101-110

61 Breitschwertdt, E.B. & Kordick, D.L. Clin.Microbiol.Rev. **13** 428-438

guarantee killing potential pathogens. There can also be serious odor problems if the compost pile is not carefully monitored.

Restrict components of the compost pile to plant material, including any kitchen scraps used.

If you must use animal manure as a source of compost, that from horses is the safest (though not as rich in nitrogen).

If you must use animal manure, exclude material from young animals (i.e. foals and calves).

On no account should dog or cat feces be added to the compost pile.

If you must use animal manure, avoid contaminating finished compost with raw manure - have a separate set of tools to handle manure, and store compost well away from fresh manure.

Invest in a compost thermometer to ensure that the pile reaches the recommended temperature, and follow current procedures for turning the pile and keeping it aerated.

If the material to be composted is low in nitrogen rather than using manure, add a small amount of fertilizer or an organic source such as oil seed meal. Such materials are available commercially, specially formulated for use in small scale composting.

It is important to prevent the compost pile from becoming water logged. If it contains animal manure, rainwater runoff could well contaminate the garden site and any well water. The design of the pile must exclude pest animals, birds and insects.

If there are stray or feral animals in the area, or rats or other wild animals such as raccoons frequent the garden, regularly scout the site for animal droppings. Promptly remove and dispose of such material in a plastic bag.

Wet down dusty areas on previously undisturbed sites before clearing or cultivating.

Use an appropriate facemask when turning a compost pile, entering a storage shed (especially if it is dusty) and clearing out a new garden site, particularly if it is one where birds may have roosted. A facemask should also be worn on entering any previously abandoned structures that may be part of a new garden site, especially if there is evidence of a rat infestation.

- Wear appropriate clothing, including gardening gloves, a long sleeved shirt or blouse and sturdy footwear. Never allow anybody, particularly children onto the garden site with bare feet.

- If children are involved in the garden they must be adequately supervised, with a designated person having the responsibility in a community garden. Keep them away from wildlife or stray animals, watch for signs of pica (eating dirt), and make sure that they do not consume any produce from the garden before it is thoroughly washed. Do not allow children to play in areas of standing water.

- If feasible, try to level out the garden site to minimize pooling of water. Do not allow objects that could collect water to remain on site after you finish working in the garden.

- Try to avoid gardening just before sunset and after sunrise (periods when mosquitoes are active,) during the summer rainy season, particularly if there is heavy rain after a prolonged dry spell. If this is not possible, wear a long sleeved shirt/blouse and long pants and use an insect repellent containing at least 15% DEET (less for children). With cotton, nylon and wool based fabrics the product can be applied directly on clothing.

- All animal bites should receive prompt medical attention.

- Before gardening, consult a health professional as to what precautions you should take if you believe you may suffer from any medical condition that could make you more susceptible to infection. Such conditions could include but are not limited to HIV/AIDS, cancer treatment, immunosuppressive drug therapy, previous splenectomy, pregnancy, diabetes, alcoholism or chronic lung disease.

Further Sources of Information

For relevant horticultural practices, including composting, as well as further information on the infectious agents described above, consult the following federal/state website resources:

Centers for Communicable Diseases (CDC) - http://www.cdc.gov/
Search the entire site for specific information, or consult the A-Z fact sheets on specific infectious diseases.

Florida Department of Health - http://www.doh.state.fl.us/
Information on Florida health concerns, with information sheets on infectious diseases of importance to Florida residents (go to Bureau of Epidemiology).

Miami-Dade County Health Department - http://www.dadehealth.org/
Information on local health related matters including disease statistics for Miami-Dade County.

Also lists contacts for reporting any suspected disease outbreaks.

Center for Food Safety and Applied Nutrition, United States Food and Drug Administration - http://vm.cfsan.fda.gov/
Extensive information is posted on food safety issues.

National Center for Biotechnology Information http://www4.ncbi.nlm.nih.gov/
Select "PubMed" and search the National Library of Medicine's holdings of biomedical journals and periodicals if you wish to access more in depth information on any of the pathogens listed above.

University of Florida Institute of Food and Agricultural Sciences - http://edis.ifas.ufl.edu/ Search this site for current information on both horticultural topics (e.g. composting), arthropod vectors of disease and zoonotic parasites.

Florida Medical Entomology Laboratory, University of Florida http://fmel.ifas.ufl.edu Up to date information on disease vectors in Florida

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