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ABSTRACT

In a preliminary study, the cargo, packaging, the inside, and the outside of 102 air cargo containers were inspected for the presence of contaminants. Most of the contaminants were lying loose inside the containers, and the packaging and cargo were almost wholly free of contaminants. Based on these findings, a larger sample of 991 containers was examined, with attention focused on contaminants in and on the container, without recording the details of the cargo carried within but inspecting the wooden packing. The sample was randomly selected from containers landed at Auckland, Wellington, and Christchurch airports in the period from April to December 1999. The containers were examined in the unpacking sheds at the airports and all soil, plant, animal, and inorganic contaminants found on the outside of and inside the container during and after unpacking were collected. Isolations were made for fungi from all soil samples (from 51 containers) collected. All plant material was examined microscopically for fungi. Insects, spiders, and other invertebrates were collected. A container was classified as "potentially quarantinable" if any of the contaminants found in or on it included viable pests or viable fungi belonging to genera which include plant pathogens, as the presence of such organisms indicated the potential risk posed by this particular pathway. Of the 991 containers examined, 750 (75.7%) carried no contaminants, 110 (11.1%) carried only non-quarantinable contaminants, and 131 (13.2%) carried potentially quarantinable contaminants. The quarantinable contamination rate of containers originating from different parts of the world varied from region to region; it was 18.2% for Australia, 16.4% for Europe, 9.4% for North Asia, 7.8% for North America, 5.9% for South-east Asia, and 5.1% for the Pacific. There were few regional differences in the proportion of quarantinable contaminants to the total number of contaminants. Very few contaminants (3.3%), none quarantinable, were associated with packaging. The quarantinable contamination rate varied from 0.0% for baggage containers to 19.6% for open-sided containers. Foliage, twigs, fruit, seed, and woody material made up 62% of all sources of contaminants and soil was the next most common (23%) source. Most of the contaminants were found inside the containers; only 0.8% of the contaminants were found solely on the outside.

The finding that fresh plant material carrying plant pests and pathogens is common inside air cargo containers suggests that these containers are a pathway by which such

harmful organisms could enter New Zealand. The fact that pest and pathogen incursions similar to those found during the air container survey have been detected in the vicinity of airport cargo sheds provides a strong link to this pathway. The training of facility operators working with the air cargo containers in managing the biosecurity risks from this pathway and the monitoring of their performance are important. The removal of residues and the safe disposal of all material collected from empty containers as soon as possible after the containers are unpacked is essential to minimise the risk of introduction of undesirable organisms.

Keywords: quarantine; risk; air cargo containers.

INTRODUCTION

The potential of sea-borne cargo containers and their contents to serve as carriers of exotic pests of forest trees has been the subject of a number of studies (Bulman 1992, 1998; Gadgil *et al.* 2000; Stanway *et al.* 2000). The risk associated with air cargo containers has not been assessed. The studies reported here were initiated by the Ministry of Agriculture and Forestry to fill this gap. The object was to examine the contaminants carried on and in air containers and to assess the magnitude of the potential risk posed by this particular pathway. The emphasis, therefore, was on determining whether a contaminant harboured living organisms belonging to taxa with plant pathogenic or phytophagous species when it reached New Zealand.

As nothing was known of the contamination rate of air containers or their contents, a pilot study was first carried out in which the outside and the inside of the containers, the packaging, and the cargo were all examined for contaminants. A second major study then looked in detail at the main sources of contaminants identified in the pilot study.

PILOT STUDY

Material and Methods

This study was carried out at the Auckland International Airport from August to October 1998. Altogether 102 air cargo containers were randomly selected at an average of 3.5 containers per day. Selected containers were examined as they were being unpacked to ensure that any loose material in or on the container was not swept or blown away. After the container was unpacked, the external surfaces, the interior, and any wrapping were inspected. The type and quantity of packaging and the nature of the cargo were recorded and then inspected. Any soil or mineral contaminants as well as all organisms and organic matter found were collected, sealed in polythene bags or plastic containers, and sent to the New Zealand Forest Research Institute for examination. The inspections were carried out by the airport quarantine officers of the Ministry of Agriculture and Forestry. Two audits were carried out during the survey to verify that the procedures were being followed as specified to ensure the data collected were consistent and accurate.

Results

Of the 102 containers examined, 31 (30%) contained a total of 87 contaminants, mostly as loose debris in the interior (Table 1). The packaging and the cargo were almost entirely free of contaminants. There were 912 consignments of cargo made up of 9795 individual

TABLE 1–Number and location of contaminants found in the pilot study

Location on container	Number of contaminants	Percentage of total
Inside (loose)	59	51
Side	5	5
Top	16	14
Wrapping	7	6
Sub-total	87	76
Packaging associated with cargo	28	24
Total	115	100

items in the 102 containers and only 28 items had contaminants associated with them (Appendix 1). Bark was the most common cargo contaminant, found on 16 items, followed by fungi on 12 items, and insect damage was found on one item. In all but one instance, the severity of contamination was classified as minor.

MAIN STUDY

Material and Methods

The results of the pilot study showed that the packaging and cargo in the air cargo containers posed very little risk. It was, therefore, decided to focus the main study on the contaminants carried on and inside the containers and not to record the cargo details but only note any contaminated packaging.

Sample size

Assuming (a) that the contaminated containers are distributed randomly through the container population, (b) that the contamination rate is about 30% as shown in the pilot study, and (c) that the mean contamination rate should be established to within 10% (as assessed using a 95% confidence interval), a sample size of 1000 containers was determined upon following the binomial confidence limits tables of Mainland *et al.* (1956).

Sampling method

New Zealand has three major international airports (Auckland, Wellington, and Christchurch) which are capable of handling aircraft carrying air containers. The majority of the containers are landed at Auckland. Each airport was assigned a target number of containers to be sampled, based on the total number of containers expected to be landed at that particular airport. In Auckland, five flights were randomly selected each day and one container per flight was randomly selected from the air manifest for inspection. In Wellington two flights per week and in Christchurch one flight per day were randomly selected, and one container per flight was randomly chosen from the air manifest for inspection. No distinction was made by type when containers were picked for inspection. The numbers of containers examined and their region of loading are given in Table 2.

Sampling period

It was considered important to cover the Northern Hemisphere summer period when pests and pathogens are likely to be most active, and the sampling period extended from April to December 1999.

TABLE 2–Numbers of containers examined from different countries and regions of loading, and air trade volume (tonnes) imported during April and August.

Region of loading	Country of loading	Containers (total)	Containers (%)	Quantity imported (tonnes)	Quantity imported (%)
Australia	Australia	500	50.5	6847	52.2
East Asia	China, Japan, South Korea, Taiwan	96	9.7	1539	11.7
Europe	Belgium, France, Germany, Italy, Netherlands, Sweden, Switzerland, United Kingdom	55	5.5	265	2.0
North America	Canada, United States	102	10.3	1945	14.8
Pacific	Fiji, Hawaii, Rarotonga, Tahiti, Tonga, Western Samoa	59	6.0	473	3.6
South America	Argentina, Brazil	3	0.3	5	0.1
South Asia	India	3	0.3	-	-
South-east Asia	Hong Kong, Indonesia, Malaysia, Singapore, Thailand	168	17.0	2028	15.5
Other	Israel, not recorded, South Africa	5	0.5	9	0.1
Total		991	100.0	13111	100.0

Examination procedure

Containers

All selected containers were examined in the unpacking sheds at the airport, and the inspections were carried out by the quarantine officers of the Ministry of Agriculture and Forestry. As the container was being unpacked, loose plant, animal, or mineral debris caught in the packaging or cargo was looked for and, after the unpacking was complete, the external surfaces were examined. The interior of the container was then inspected. Any soil or mineral contaminants, as well as all organisms and organic matter found, were collected and placed in polythene bags or plastic containers which were then sealed and forwarded to the New Zealand Forest Research Institute for detailed examination. Details of port of loading, country of origin, packaging, and location of contaminants were entered for each container on a survey form.

Contaminants

Soil: Soil samples from each container were thoroughly mixed and air-dried. Isolations for fungi were made from all samples received by sprinkling isolation plates with 0.1 g of the air-dried sample. Three specialised media (Cycloheximide agar (Brasier 1981), a modified Nash-Snyder medium (Nelson *et al.* 1983), and PAR medium (Kannwischer &Mitchell 1978)) and a general medium (3% malt extract agar) were used for the isolations. Plates were incubated at 18°C. After 2 weeks, the plates were examined under a stereomicroscope and fruiting structures were picked off and examined under a research microscope. Fungi were identified, usually to genus and sometimes to species.

Plant material: Leaves, twigs, and other plant material, including pieces of wood, after examination for any live insects, were placed in damp chambers for 2–3 days at room temperature. Fruiting and other structures which could aid identification were picked off and

examined under a research microscope. Sketches were made and measurements taken of these structures. Fungi were identified to genus and, if possible in the time available, to species.

Animal material: All insects, spiders, and other invertebrates were examined, under a stereomicroscope when necessary and identified to order and, if possible in the time available, to genus and to species.

Classification of contaminants: Contaminants (living organisms, and organic and inorganic material containing living organisms) found in or on air cargo containers were classified either as "non-quarantinable" or "potentially quarantinable". All contaminants which could be identified as saprophytic or saprophagous were classified as "non-quarantinable". Potentially quarantinable contaminants were:

(a) Soil samples which yielded either fungi belonging to genera which include forest plant or forest products pathogens (Holliday 1989), (for example, *Cladosporium, Colletotrichum, Fusarium, Leptographium, Ophiostoma, Pythium, Verticillium*);

(b) Woody or herbaceous plant material which carried viable fruiting structures which belonged to fungal genera which include pathogens—for example, *Ascochyta, Coniothyrium, Lophodermium, Phoma, Uromycladium*;

(c) Live insect pests and viable egg masses of insect pests. The term "quarantinable" applied to a contaminant customarily implies the presence of a "quarantine pest" which is likely to be deposited in a place suitable for its establishment and further spread, eventually leading to damage. We have assumed that if a potential quarantine pest is present in a mass of soil or as sporulating fruiting bodies on a plant part or as viable egg masses, then there is a reasonable chance that it could become established.

We decided that no value was to be gained from attempting to establish whether any of the "potentially quarantinable" organisms were classifiable as "quarantine pests". The definition of a "quarantine pest" is "A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled" (FAO 1996). In the first place, the relevance to forestry of a list of "quarantine pests" is questionable, given our imperfect knowledge of forestry pests and pathogens and the great difficulty in predicting how an exotic organism would behave under New Zealand conditions. Secondly, it is very difficult, if not altogether impossible, to establish the pest status of fungal species. We classified all fungi which belonged to genera containing plant pathogenic species as "potentially quarantinable", regardless of whether representatives of these genera or species were recorded as being present in New Zealand. The record of the presence of a morphologically-characterised taxonomic species in a country does not mean that all subspecies, formae speciales, varieties, or races of that species are present in the country.

Most plant pathogenic fungal species are not a single genetic entity but contain many different forms which vary in pathogenicity and host specificity. These forms are morphologically indistinguishable. *Fusarium oxysporum* Schlechtendal provides a good example of such a variable species. Fifty-four formae speciales of *F. oxysporum,* many subdivided into a number of races, were recognised in the world in 1989 (Holliday 1989); only 12 of these were recorded in New Zealand (Pennycook 1989) and it would be impossible

to determine from a morphological examination whether a new isolate of *F. oxysporum* (say, from soil adhering to a container) belonged to a forma specialis, let alone to a race, already present in New Zealand. To give another example, *F. subglutinans* (Wollenweber & Reinking) Nelson *et al.* is recorded from maize in New Zealand (as *F. moniliforme* var. *subglutinans* (Pennycook 1989)); *F. subglutinans* f. sp. *pini* causes a very serious disease of *Pinus* spp. in North America (Correll *et al.* 1991) but it cannot be distinguished from the *F. subglutinans* on maize by morphological characters. It would be disastrous for New Zealand plantation forestry if all forms of *F. subglutinans* were allowed entry simply because one form is known to be present here. To add to the difficulty, not all the forms within a species are recorded in the literature or even recognised. For example, no forms or varieties of *Cyclaneusma minus* (Butin) DiCosmo *et al.*, a needle pathogen of *Pinus* spp. of worldwide distribution, are recorded in the literature but at least four forms of this fungus are present in New Zealand (Dick *et al.* 2001) and it is probable that there are many others in different parts of the world. The employment of molecular techniques would overcome some of these difficulties in identification but they are too time-consuming for routine quarantine identification.

These difficulties are generally recognised by quarantine authorities, most of whom regard all exotic pathogenic fungi as quarantinable. The Australian Quarantine and Inspection Service does not allow importation of *Pinus radiata* D. Don material which could carry *Dothistroma pini* Hulbary, although this pathogen has been present in Australia since 1975. The U.S. Animal and Plant Health Inspection Service has prohibited the importation of *P. radiata* logs with *Sphaeropsis sapinea* (Fries) Dyko & Sutton (*Diplodia pinea* (Desm.) Kickx) infection, yet both the host and the pathogen are indigenous to the United States. We prefer to follow this precautionary approach and have regarded all pathogenic fungi as potential pests which should be excluded as far as is practicable.

In our view, all contaminants which we have classified as potentially quarantinable should be regarded as quarantinable for practical purposes. For example, if soil on a container originating from North America is shown to be carrying a species of *Fusarium*, then it is obviously capable of providing a pathway by which the highly pathogenic *F. subglutinans* f.sp. *pini* could reach New Zealand, although this particular species may not be present in the particular soil sample examined. Soil, *per se,* has always been treated as a quarantine risk because it is capable of carrying a wide and unpredictable range of plant, animal, and human pathogens and invertebrate pests which are often very difficult to isolate and to identify. Following this logic, we have referred to all potentially quarantinable contaminants as "quarantinable" in this document.

Results

Of the 991 containers examined, 241 (24%) carried one or more contaminants and, in all, 848 individual contaminants were identified. One hundred and thirty-one (13%) containers carried potentially quarantinable (as defined in the section above) contaminants. The types and numbers of contaminants found are listed in Appendix 2. A container which carried one or more potentially quarantinable contaminants was classified as "quarantinable".

Soil samples

Soil (including silt, gravel, sand, grit, and potting mix) was present in 51 containers. Fungal isolations were made from all soil samples collected. Soil from 18 containers (35%)

yielded only saprophytic fungi and that from 33 containers (65%) yielded fungi belonging to genera which include plant pathogens (Table 3). Most containers carried soil that yielded more than one pathogenic genus. Only one container carried soil from which one pathogenic genus was isolated, five containers carried soil from which two different pathogenic genera were isolated, 15 containers carried soil with three genera, eight containers had four different genera, and four containers had five. Species of *Fusarium* were isolated most frequently (73% of containers with soil which yielded species belonging to pathogenic genera), followed by *Cladosporium* spp. (57%), *Verticillium* spp. (27%), *Cylindrocladium* spp. (18%), *Leptographium* spp. (12%), *Phoma* spp. (12%), *Rhizoctonia* spp. (6%), and *Pythium* spp. (6%).

Sources of contaminants and their location on the containers

The sources of contaminants and their location in or on the containers are given in Table 4. Foliage, fruit and seed, and woody material made up 62% of all sources of contaminants. Foliage was often fresh and frequently carried pathogenic fungi and other pests. Soil was the

TABLE 3–Genera of fungi containing plant pathogenic species isolated from soil samples and the numbers of containers from which members of each genus were isolated.

Genus*	Containers	
	(No.)†	(%)
Acremonium	1	3
Alternaria	2	6
Aureobasidium	5	15
Botrytis	3	9
Cladosporium	5	57
Colletotrichum	2	6
Curvularia	1	3
Cylindrocladium	6	18
Drechslera	4	12
Fusarium	24	73
Graphium	2	6
Helminthosporium	3	9
Leptographium	4	12
Oidiodendron	2	6
Phialophora	3	9
Phoma	4	12
Phomopsis	2	6
Pithomyces	1	3
Pythium	2	6
Rhizoctonia	2	6
Verticicladiella	2	6
Verticicladium	1	3
Verticillium	9	27

* Isolates of species of fungi belonging to pathogenic genera were obtained from 33 containers.

† Although several isolates of species belonging to a pathogenic genus were usually obtained from one soil sample from a container, the presence of the genus is recorded only once for that container. As isolates belonging to a number of pathogenic genera were obtained from a soil sample from one container, the total number of isolates is greater than the 33 containers from which soil samples containing pathogenic fungi were obtained.

TABLE 4–Sources of contamination and their location on or in the containers

Sources of contamination	Total contaminants found		Location of contaminants							
			Inside		Top		Sides		Wrapping	
	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Soil	197	23.2	196	99.5	0	0.0	0	0.0	1	0.5
Fruit/seed	48	5.7	46	95.8	1	2.1	0	0.0	1	2.1
Foliage	419	49.4	401	95.7	16	3.8	0	0.0	2	0.5
Woody material	58	6.8	58	100.0	0	0.0	0	0.0	0	0.0
Insects – eggs	1	0.1	1	100.0	0	0.0	0	0.0	0	0.0
– larvae	4	0.5	3	75.0	1	25.0	0	0.0	0	0.0
– adults	24	2.8	20	83.3	4	16.7	0	0.0	0	0.0
Other animals	11	1.3	8	72.7	3	27.3	0	0.0	0	0.0
Water ponding	3	0.4	1	33.3	1	33.3	1	33.3	0	0.0
Indeterminate, debris	55	6.5	53	96.4	1	1.8	0	0.0	1	1.8
Packaging	28	3.3	28	100	0	0.0	0	0.0	0	0.0
Total	848	100.0	815	96.1	27	3.2	1	0.1	5	0.6

next most-common contaminant source (23%). Live insects and egg masses were found infrequently and were not of major quarantine significance. Contaminants of other animal origin were very few and of no consequence. A not uncommon contaminant, of no concern to plant health but one which poses a major threat to human health (Ministry of Health 1999), comprised the unconsumed portions of several cigarettes, both handmade and manufactured. Most of the contaminants were found inside the containers; only 0.8% of the contaminants were found solely on the outside (Table 5).

Contaminants associated with packaging

Only 28 contaminants (3.3% of the total) were found in association with packaging (Table 4). Two of these were quarantinable — *Ophiostoma piceae* (Münch) H. & P.Sydow was isolated from decay in a crate, and an *Ophiostoma* sp. was isolated from decay in a case of machinery. Other contaminants were primarily minor amounts of bark, and old insect damage.

TABLE 5–Locations of contaminants and numbers of containers in each category

Location of contaminants	Total containers		Containers with			
			Non-quarantinable contaminants		Quarantinable contaminants	
	(No.)	(%)	(No.)	(%)	(No.)	(%)
No contaminants	750	75.7				
Inside	225	22.7	102	10.3	123	12.4
Top	8	0.8	4	0.4	4	0.4
Inside and side	3	0.3	0	0.0	3	0.3
Inside and wrapping	2	0.2	2	0.2	0	0.0
Inside and top	1	0.1	0	0.0	1	0.1
Top and wrapping	1	0.1	1	0.1	0	0.0
Wrapping	1	0.1	1	0.1	0	0.0
Grand total	991	100.0	110	11.1	131	13.2

Contamination and the country of loading

Contamination rates for containers loaded on New Zealand-bound aircraft in different regions are given in Table 6. It is recognised that all contaminants were not necessarily acquired in the region in which the containers were loaded on the aircraft but judging by the nature of the contaminants, especially plant parts (leaves of *Eucalyptus* spp. and *Acacia* spp. on containers loaded in Sydney, for example), it was considered reasonable to assume the contaminants originated at or near the port of loading. The quarantinable contamination rate was generally low; containers from Australia had a quarantinable contamination rate of 18.2%, Europe 16.4%, North Asia 9.4%, North America 7.8%, South-east Asia 5.9%, and the Pacific 5.1%. Containers from other regions carried no quarantinable contaminants.

The proportion of quarantinable contaminants to the total number of contaminants varied from 33% to 51% for the containers from those regions in which quarantinable contaminants were found (Table 7). The proportions of the different types of contaminants were generally very similar for all regions (Table 8).

Contamination and the types of containers

The containers examined in the course of the study were classified into four main types and a fifth "other" category comprising all other miscellaneous types. The quarantinable contamination rate varied from 0.0% for the very few baggage containers examined to 19.6% for open-sided containers (Table 9). The percentage of quarantinable contaminants in the total number of contaminants was similar — about 50% — for all types of containers (Table 10).

Variation in contamination between airports

There was some variation in the percentage of quarantinable contaminants in the total number of contaminants found at the three airports (Table 11). This variation can be ascribed

TABLE 6–Contamination rates for containers from different regions

Region of loading	No. of containers examined	Containers with							
		No contaminants		Non-quarantinable contaminants		Quarantinable contaminants		95% confidence intervals for quarantinable contaminants	
		(No.)	(%)	(No.)	(%)	(No.)	(%)	Lower (%)	Upper (%)
Australia	500	345	69.0	64	12.8	91	18.2	14.7	21.6
East Asia	96	79	82.3	8	8.3	9	9.4	4.2	16.4
Europe	55	38	69.1	8	14.5	9	16.4	7.8	28.8
North America	102	88	86.3	6	5.9	8	7.8	3.5	15.2
Other	5	4	80.0	0	0.0	1	20.0	0.5	71.6
Pacific	59	53	89.8	3	5.1	3	5.1	1.0	13.9
South America	3	3	100.0	0	0.0	0	0.0	–	–
South Asia	3	2	66.7	1	33.3	0	0.0	–	–
South-east Asia	168	138	82.2	20	11.9	10	5.9	2.9	10.5
Total	991	750	75.7	110	11.1	131	13.2	11.0	15.2

TABLE 7–Proportions of non-quarantinable and quarantinable contaminants on containers from different regions

Region of loading	No. of contaminants found	Non-quarantinable contaminants		Quarantinable contaminants	
		(No.)	(%)	(No.)	(%)
Australia	580	282	48.6	298	51.4
East Asia	48	26	54.2	22	45.8
Europe	64	35	54.7	29	45.3
North America	51	26	51.0	25	49.0
Other	3	0	0.0	3	100.0
Pacific	11	7	63.6	4	36.4
South America	0	0	0.0	0	0.0
South Asia	1	1	100.0	0	0.0
South-east Asia	90	60	66.7	30	33.3
Total	848	437	51.5	411	48.5

TABLE 8–Type of contaminants on containers from different regions

Region of loading	Total	Fungi		Insect		Plant		Soil		Other	
		(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)	(No.)	(%)
Australia	580	286	49.3	28	4.8	185	31.9	33	5.7	40	8.3
East Asia	48	25	52.1	4	8.3	15	31.3	1	2.1	1	6.2
Europe	64	31	48.5	2	3.1	16	25.0	5	7.8	6	15.6
North America	51	29	56.9	2	3.9	11	21.6	5	9.8	4	7.8
Pacific	11	2	18.2	3	27.3	6	54.5	0	0.0	0	0.0
South America	0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
South Asia	1	0	0.0	0	0.0	0	0.0	0	0.0	1	100.0
South-east Asia	90	37	41.1	7	7.8	25	27.8	7	7.8	12	15.5
Other	3	2	0.2	0	0.0	1	0.1	0	0.0	0	0.0
Grand total	848	412	48.6	46	5.4	259	30.5	51	6.0	80	9.5

TABLE 9–Contamination rates for different container types

Container type	No. of containers examined	Containers with					
		No contaminants		Non-quarantinable contaminants		Quarantinable contaminants	
		(No.)	(%)	(No.)	(%)	(No.)	(%)
Baggage	6	6	100.0	0	0.0	0	0.0
Open Sided	357	229	64.1	58	16.2	70	19.6
Pallet	95	87	91.6	8	8.4		0.0
"Pig"	260	185	71.2	35	13.5	40	15.4
Other	273	243	89.0	9	3.3	21	7.7
Total	991	750	75.7	110	11.1	131	13.2

TABLE 10–Proportions of non-quarantinable and quarantinable contaminants on different container types

Container type	No. of contaminants found	Non-quarantinable contaminants		Quarantinable contaminants	
		(No.)	(%)	(No.)	(%)
Baggage	0	0	0.0	0	0.0
Open sided	477	232	48.6	245	51.4
Pallet	10	10	100.0	0	0.0
"Pig"	283	160	56.5	123	43.5
Other	78	35	44.9	43	55.1
Total	848	437	51.5	411	48.5

TABLE 11–Total number of contaminants found at each airport

Port	No. of contaminants found	Non-quarantinable contaminants		Quarantinable contaminants	
		(No.)	(%)	(No.)	(%)
Auckland	763	388	50.9	375	49.1
Christchurch	62	38	61.3	24	38.7
Wellington	23	11	47.8	12	52.2
Total	848	437	51.5	411	48.5

largely to the different contamination rates of containers originating in different regions and the marked variation in the proportions of containers from various regions landed at each airport. Most of the contaminants (87%) found at Wellington airport came from containers from Australia and the percentage of quarantinable contaminants found at Wellington (52.2%) was very close to the percentage of quarantinable contaminants in contaminants from Australia (51.4%). Christchurch airport had a lower percentage of quarantinable contaminants (38.7%); 45% of the contaminants found there were from Australia (quarantinable contamination percentage 51.4%) and 53% came from South-east Asia (quarantinable contamination percentage 33.3%). The remaining 2% came from East Asia. The contaminants found at Auckland came from all the regions sampled in about the same proportions as in the total sample.

DISCUSSION

Air cargo containers originating from the regions from which more than 50 containers were inspected were all found to carry quarantinable contaminants. A little more than half (50.5%) of the total number of containers inspected came from Australia and these had a quarantinable contamination rate of 18.2% (95% confidence interval 14.7–21.6%). The quarantinable contamination rate for Europe was 16.4% (95% confidence interval 7.8–28.8%), that for East Asia 9.4% (95% confidence interval 4.2–16.4%), for North America 7.8% (95% confidence interval 3.5–15.2%), for South-east Asia 5.9% (95% confidence interval 2.9–10.5%), and for the Pacific region 5.1% (95% confidence interval 1.0–13.9%).

Only three containers were sampled each from South America and South Asia. No quarantinable contaminants were found in these containers but, in view of the smallness of the sample, this result cannot be taken as reliable.

The quarantinable contamination rate for the 991 containers sampled was 13.2% (95% confidence interval 11.0–15.2%). The external surfaces of containers were generally very clean; only 0.8% of the containers had quarantinable contaminants on the outside. This contrasts with the condition of shipping containers, 23.4% of which were found to carry quarantinable contaminants on the outside (Gadgil *et al.* 2000). This difference needs to be treated with some caution. Most of the contaminants (61.5%) on shipping containers were on the bottom but the lower outside surface of air cargo containers was not examined in the main study. The decision not to examine the bottom was based on the pilot study in which no contaminants were found on the lower outside surface. This observation, coupled with the fact that air cargo containers are constructed with a smooth flat bottom for movement by rollers, led to the conclusion that the extra expense in time and money involved in placing air containers on stands to inspect the bottom was not justified. Half of the few contaminants found on the outside of the containers were on the top and most of these were leaves and twigs. There were no containers with quarantinable contaminants only on the outside; the few containers that carried quarantinable contaminants on the outside also had quarantinable contaminants inside.

All quarantinable contaminants inside the air containers were lying loose and none were associated with the cargo packaging. Fresh leaves and twigs made up the largest proportion of these contaminants. If not detected during routine quarantine examination at the airport, it devolves on the person unpacking the container to sweep up all contaminants and place them in a MAF-approved container for safe disposal. The plant material found inside containers in the course of this study carried live pests (e.g., *Ophelimus* spp.) and plant pathogens (e.g., *Ascochyta* sp., *Aulographina eucalypti* (Cooke & Massee) von Arx & Müller, *Botryosphaeria dothidea* (Mougeot : Fries) Cesati & de Notaris, *Cladosporium* sp., *Coniothyrium* sp., *Colletotrichum dematium* (Fries) Grove, *Cryptosporiopsis* sp., *Discula* sp., *Hainesia lythri* (Desmazières) Höhnel, *Mycosphaerella* spp., *Phoma* sp, *Phomopsis* sp., *Puccinia graminis* Persoon, *Sarcostroma* sp., *Uromycladium acaciae* (Cooke) Sydow, *U. robinsonii* McAlpine, *Vermisporium eucalypti* (McAlpine) Nag Raj). A number of pests that could be carried only on live plant material and leaf pathogens have been first recorded in New Zealand on trees within a few hundred metres of the air cargo sheds at Auckland airport. Examples are: pests — *Phylacteophaga froggatti* Riek (Kay 1986), *Cardiaspina fiscella* Taylor (Crabtree 1997); pathogens — *Cryptosporiopsis eucalypti* Sankaran & Sutton (Gadgil & Dick 1999), *Cladosporium* sp. and *Elsinoe* sp. (Williams 1992). The finding that fresh plant material carrying plant pests and pathogens is carried inside air containers, coupled with fact that newly introduced pests and pathogens have been found in close vicinity of the airport, strongly suggests that the organisms inside the containers may escape disposal, and that air cargo containers provide a pathway by which exotic pests and pathogens can become established in New Zealand.

Soil was the next most-common contaminant inside containers. Fungi belonging to a number of genera containing plant pathogenic species were isolated from the soil, e.g., species of *Fusarium, Cladosporium, Phoma, Verticillium, Alternaria, Aureobasidium, Leptographium, Rhizoctonia*, and *Pythium.* There are no records of exotic soil-borne plant

pathogens becoming established near airports in New Zealand, but this study found that 3.3% of the containers examined contained soil carrying plant pathogenic species of fungi and the associated risk, although probably small, should not be ignored.

There were no major regional differences in the proportion of quarantinable contaminants to the total number of contaminants, nor were quarantinable contaminants associated with any particular container type. Thus contaminants, mainly as live plant parts carrying pests and pathogens, from all regions present a quarantine risk which varies from region to region but is not absent from any major region.

CONCLUSION

Air cargo containers appear to present a significant quarantine risk in view of the past records of introductions of leaf-borne pests near international airports and the number of quarantinable contaminants found during this study. The external surfaces are generally clean and carry little material of quarantine significance and very few quarantinable contaminants are associated with the cargo or with the packaging. The main risk comes from fresh plant parts, mainly leaves and twigs, lying loose inside the container. Ensuring the safe transport of containers between discharge and unpacking sites, the recovery of residues when the container is unpacked, the cleaning of the empty container, and the safe disposal of all material collected is very important to the management of the risk from this pathway. The risk from contaminants carried in the containers is higher than that from packing associated with the cargo and its containment should be accorded the higher priority for resources.

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REFERENCES

BRASIER, C.M. 1981: Laboratory investigations of *Ceratocystis ulmi*. Appendix II *in* "Compendium of Elm Diseases", American Phytopathological Society, St. Paul.

BULMAN, L.S. 1992: Forestry quarantine risk of cargo imported into New Zealand. *New Zealand Journal of Forestry Science 22*: 32–38.

———1998: Quarantine risk posed to forestry by full container loads and efficiency of FCL door inspections. *New Zealand Journal of Forestry Science 28*: 335–346.

CORRELL, J.C.; GORDON, T.R.; McCAIN, A.; FOX, J.W.; KOEHLER, C.S.; WOOD, D.L.; SCHULTZ, M.E. 1991: Pitch canker in California: pathogenicity, distribution and canker development on Monterey pine (*Pinus radiata*). *Plant Disease 75*: 676–682.

CRABTREE, R. 1997: *Cardiaspina. New Zealand Forest Research Institute, Forest Health News 64*: 2.

DICK, M.; SOMERVILLE, J.G.; GADGIL, P.D. 2001: Variability in the fungal pathogen. Pp. 12–19 *in* Bulman, L.S.; Gadgil, P.D. (Ed.) "Cyclaneusma Needle-cast in New Zealand". *New Zealand Forest Research Institute, Forest Research Bulletin No. 222.*

FAO 1996: International Standards for Phytosanitary Measures, Part 1 – Import Regulations. *Food and Agriculture Organization of the United Nations, Rome, Secretariat of the International Plant Protection Convention, Publication No.2.*

GADGIL, P.D.; DICK, M. 1999: Fungi silvicolae Novazelandiae: 2. *New Zealand Journal of Forestry Science 29*: 440–458.

GADGIL, P.D.; BULMAN, L.S.; CRABTREE, R.; WATSON, R.N.; O'NEIL, J.C.; GLASSEY, K.L. 2000: Significance to New Zealand forestry of contaminants on the external surfaces of shipping containers. *New Zealand Journal of Forestry Science 30*: 341–358.

HOLLIDAY, P. 1989: "A Dictionary of Plant Pathology". Cambridge University Press, Cambridge.

KANNWISCHER, M.E.; MITCHELL, D.J. 1978: The influence of a fungicide on the epidemiology of black shank of tobacco. *Phytopathology 68*: 1760–1765.

KAY, M.K. 1986: *Phylacteophaga froggatti* Riek (Hymenoptera:Pergidae). *New Zealand Forest Service, Forest Research Institute, Forest and Timber Insects in New Zealand No. 64.*

MAINLAND, D.; HERRERA, L.; SUTCLIFFE, M.I. 1956: "Tables for Use with Binomial Samples". New York University College of Medicine, New York.

MINISTRY OF HEALTH 1999: "Our Health, Our Future: Hauora Pakari, Koiora Roa: The Health of New Zealanders 1999". Ministry of Health, Wellington.

NELSON, P.E.; TOUSSOUN, T.A.; MARASAS, W.F.O. 1983: "An Illustrated Manual for the Identification of *Fusarium* species". Pennsylvania State University Press, University Park.

PENNYCOOK, S.R. 1989: "Plant Diseases recorded in New Zealand", Vol. 2. Plant Diseases Division, DSIR, Auckland.

STANWAY, M.A.; ZALUCKI, M.P.; GILLESPIE, P.S.; RODRIGUEZ, C.M.; MAYNARD, G.V. 2000: Pest risk assessment of insects in sea cargo containers. *Australian Journal of Entomology 40*: 180–192.

WILLIAMS, M.C.M. 1992: Leafspots on *Eucalyptus*. *New Zealand Forest Research Institute, Forest Health News 6*: 1.

APPENDIX 1

NUMBER OF CONTAMINANTS FOR EACH PACKAGING AND CARGO TYPE (PILOT STUDY)

Packaging type	Cargo type	Number of items	Number of items with contaminants
Bale	Textiles	47	
Carton	Chemical	749	
Carton	Food	2171	
Carton	General	3128	
Carton	Glass	5	
Carton	Machinery	800	
Carton	Other	10	
Carton	Paper	517	
Carton	Personal	23	
Carton	Stone	2	
Carton	Textiles	1249	
Carton	Timber	4	
Carton	Unknown	261	
Crate	Chemical	13	
Crate	Food	3	
Crate	General	1	
Crate	Machinery	105	7
Crate	Paper	5	
Crate	Stone	1	
Crate	Unknown	4	
Dunnage	Other	5	2
Dunnage	Paper	2	
Other	Chemical	18	10
Other	Unknown	6	
Package	Chemical	58	
Package	General	29	
Package	Machinery	4	
Package	Other	12	
Package	Paper	37	
Package	Personal	8	
Package	Textiles	32	
Pallet	Chemical	12	
Pallet	Food	25	
Pallet	General	39	3
Pallet	Glass	8	
Pallet	Machinery	119	
Pallet	Paper	27	3
Pallet	Textiles	2	
Pallet	Timber	1	
Pallet	Unknown	11	
Piece	Chemical	5	
Piece	General	20	
Piece	Machinery	4	
Piece	Textiles	10	
Roll	Machinery	1	
Roll	Textiles	176	
Skid	General	2	
Skid	Machinery	23	3
Skid	Paper	1	
Total		9795	28

APPENDIX 2

TYPE AND NUMBER OF CONTAMINANTS FOUND IN AND ON AIR CARGO CONTAINERS

Notes: (1) Contaminants regarded as quarantinable in this study are marked with an asterisk.
(2) The contaminant number refers to one lot or mass, comprising one or more individuals, of a given contaminant on a container. For example, an insect egg mass, a nest of spiders with many hatchlings, or a swarm of fungal fruiting bodies, have been recorded as single contaminants.

	Contaminant	Number			Notes
		Live	Dead	Total	
I. FUNGI					
*	*Acremonium* sp.	1	-	1	Endophyte causing toxicosis
	Agaricus bitorquis	1	-	1	Edible mushroom
*	*Alternaria* sp.	9	-	9	Pathogens of herbaceous plants
	Alveophoma sp.	1	-	1	Saprophyte
	Amerosporium polynematoides	2	-	2	Saprophyte
*	*Ascochyta* sp.	4	-	4	Leaf and bark blotch
	Ascochytulina sp.	1	-	1	Saprophyte
	Aspergillus sp.	9	-	9	Saprophyte
*	*Asteroma* sp.	4	-	4	Leaf spots
	Asteromellopsis sp.	1	-	1	Saprophyte
*	*Aulographina eucalypti*	1	-	1	Leaf spots on eucalypts
*	*Aulographium* sp.	1	-	1	Leaf spots
*	*Aureobasidium* sp.	7	-	7	Stem pathogen
	Bartalinia sp.	1	-	1	Saprophyte
*	*Beniowskia* sp.	1	-	1	Leaf blight
	Blennoria sp.	2	-	2	Saprophyte
*	*Botryosphaeria dothidea*	2	-	2	Cankers, dieback
*	*Botryosphaeria* sp.	3	-	3	Cankers
*	*Botrytis cinerea*	3	-	3	Stem rot
*	*Botrytis* sp.	5	-	5	Stem rot
	Catenophora sp.	2	-	2	Saprophyte
	Cephalosporium sp.	5	-	5	Saprophyte
*	*Cercospora* sp.	1	-	1	Leaf blight
*	*Ceuthospora innumera*	1	-	1	Stem rot
*	*Ceuthospora* sp.	1	-	1	Stem rot
	Chaetomella acutiseta	2	-	2	Saprophyte
	Chaetomella oblonga	1	-	1	Saprophyte
	Chaetomella sp.	1	-	1	Saprophyte
	Chaetomium sp.	5	-	5	Saprophyte
*	*Chaetophiophoma trematis*	1	-	1	Leaf spots
*	*Cladosporium* sp.	28	-	28	Leaf spots
*	*Cladosporium sphaerospermum*	1	-	1	Leaf spots
*	*Colletotrichum dematium*	1	-	1	Leaf and stem rot
*	*Colletotrichum* sp.	10	-	10	Leaf and stem rot
	Conidioxyphium sp.	1	-	1	Saprophyte
	Coniosporium sp.	1	-	1	Saprophyte
*	*Coniothyrium* sp.	3	-	3	Cankers
*	*Conostroma* sp.	1	-	1	Bark necrosis
	Cryptocline cinerescens	1	-	1	Saprophyte
	Cryptocline sp.	3	-	3	Saprophyte

	Contaminant	Number Live	Dead	Total	Notes
*	*Cryptosporiopsis* sp.	2	-	2	Leaf and stem pathogen
*	*Curvularia* sp.	1	-	1	Seedling blight
*	*Cylindrocladium* sp.	6	-	6	Leaf and twig dieback
	Cylindrosporella sp.	1	-	1	Saprophyte
*	*Cytospora chrysosperma*	1	-	1	Cankers
*	*Cytospora* sp.	5	-	5	Cankers
	Decay fungi (Basidiomycetes)	5	-	5	Presumed saprophytes
*	*Diaporthe* sp.	2	-	2	Stem pathogen
	Discosporina sp.	2	-	2	Saprophyte
*	*Discula* sp.	11	-	11	Leaf spots
	Disculina sp.	1	-	1	Saprophyte
	Doratomyces sp.	2	-	2	Saprophyte
*	*Drechslera* sp.	4	-	4	Leaf and stem rot
	Epicoccum sp.	4	-	4	Saprophyte
	Fusamen sp.	1	-	1	Saprophyte
*	*Fusarium solani*	1	-	1	Root and stem rot
*	*Fusarium* sp.	25	-	25	Wilts, root rots, cankers
*	*Fusicoccum* sp.	2	-	2	Leaf and bark pathogen
	Gampsonema exile	1	-	1	Saprophyte
	Gliocladium sp.	4	-	4	Saprophyte
*	*Graphium* sp.	2	-	2	Stem pathogen
*	*Hainesia lythri*	1	-	1	Leaf and stem rot
*	*Hainesia* sp.	1	-	1	Leaf and stem rot
*	*Harknessia* sp.	2	-	2	Leaf spots
*	*Helminthosporium* sp.	3	-	3	Leaf and stem pathogen
	Hyphomycetes (not further identifiable)	32	-	32	Presumed saprophytes
	Hysterodiscula sp.	2	-	2	Saprophyte
*	*Leptodothiorella* sp.	2	-	2	Stem pathogen
*	*Leptographium* sp.	6	-	6	Root disease, cankers
*	*Leptostroma* sp.	7	-	7	Leaf pathogen
*	*Leptothyrium* sp.	2	-	2	Leaf spots
*	*Lophodermium petiolicolum*	1	-	1	Leaf cast
*	*Lophodermium* sp.	1	-	1	Needle-cast
*	*Melampsoridium betulinum*	1	-	1	*Betula* rust
*	*Melampspora* sp.	1	-	1	Rusts
	Microthyrium sp.	1	-	1	Saprophyte
	Monodictys sp.	2	-	2	Saprophyte
*	*Monostichella* sp.	1	-	1	Leaf spots
*	*Mycosphaerella* sp.	3	-	3	Leaf spots
	Myrothecium sp.	3	-	3	Saprophyte
*	*Oidiodendron* sp.	2	-	2	Root disease
	Ojibwaya sp.	1	-	1	Saprophyte
*	*Ophiostoma piceae*	1	-	1	Stem disease, blue stain
*	*Ophiostoma* sp.	1	-	1	Wilts, blue stain
	Paecilomyces sp.	2	-	2	Saprophyte
	Penicillium sp.	9	-	9	Saprophyte
*	*Perenospora* sp.	1	-	1	Downy mildew
*	*Pestalotiopsis jacksonii*	1	-	1	Leaf spots
*	*Pestalotiopsis* sp.	5	-	5	Leaf spots
*	*Phacidiella* sp.	1	-	1	Leaf and stem blight
	Phaeocytostroma sp.	3	-	3	Saprophyte
*	*Phialophora* sp.	3	-	3	Wilts, leaf necrosis

	Contaminant	Number Live	Dead	Total	Notes
*	*Phloeospora* sp.	1	-	1	Leaf spots
	Phloeosporella sp.	2	-	2	Saprophyte
*	*Phoma exigua*	1	-	1	Damping off and root rot
*	*Phoma herbarum*	1	-	1	Leaf spots
*	*Phoma* sp.	19	-	19	Root rots, leaf spots
*	*Phomopsis archeri*	1	-	1	Dieback
*	*Phomopsis* sp.	8	-	8	Leaf spots, dieback
*	*Physalospora* sp.	1	-	1	Cankers
*	*Pithomyces* sp.	1	-	1	Mycotoxicoses
	Pleospora herbarum	3	-	3	Saprophyte
	Pseudodiplodia sp.	5	-	5	Saprophyte
	Pseudorobillarda sp.	1	-	1	Saprophyte
*	*Puccinia graminis*	1	-	1	Wheat rust
*	*Pyrenochaeta* sp.	1	-	1	Leaf and stem rot
	Pyrenopeziza sp.	1	-	1	Saprophyte
*	*Pythium* sp.	2	-	2	Root rots
*	*Rhizoctonia* sp.	3	-	3	Root rots
	Sarcophoma sp.	1	-	1	Saprophyte
*	*Sarcostroma* sp.	1	-	1	Leaf and twig pathogen
	Selenophoma sp.	1	-	1	Saprophyte
*	*Septoria* sp.	1	-	1	Leaf spots
	Sirodothis sp.	1	-	1	Saprophyte
*	*Sphaceloma* sp.	2	-	2	Scab
	Stachybotrys sp.	2	-	2	Saprophyte
	Stemyphylium sp.	7	-	7	Saprophyte
	Stictis stellata	1	-	1	Saprophyte
*	*Stigmina* sp.	1	-	1	Leaf and twig pathogen
	Trichoderma sp.	3	-	3	Saprophyte
	Trichoderma viridae	1	-	1	Saprophyte
	Trichothecium sp.	2	-	2	Saprophyte
*	*Ulocladium* sp.	1	-	1	Leaf spots and fruit rots
*	*Uromycladium acaciae*	1	-	1	*Acacia* rust
*	*Uromycladium robinsonii*	1	-	1	*Acacia* rust
*	*Valsa* sp.	1	-	1	Cankers
*	*Venturia* sp.	1	-	1	Leaf spots and scab
*	*Vermisporium acutum*	1	-	1	Leaf spots
*	*Vermisporium eucalypti*	1	-	1	Leaf spots
*	*Verticicladiella* sp.	2	-	2	Root disease
*	*Verticicladium* sp.	1	-	1	Root disease
*	*Verticillium* sp.	10	-	10	Wilts and root rots
	Zythiostroma sp.	1	-	1	Saprophyte
	Total	**411**		**411**	
II. INVERTEBRATE ANIMALS					
	Acari	2	-	2	Mites
	Aranea: *Heteropoda venatoria*	1	-	1	New Zealand spider
*	Aranea: *Laterodectus hasselti*	1	-	1	Redback spider
	Aranea: Sparassidae	1	-	1	'Avondale-type' spider
	Aranea	4	2	6	Spiders
	Blattodea: *Laxta* sp.	-	1	1	Australian wingless cockroach
	Blattodea	-	1	1	Cockroach
	Coleoptera: Cerambycidae	-	1	1	Longhorn beetle

	Contaminant	Number Live	Dead	Total	Notes
	Coleoptera: Lyctidae	-	1	1	Powderpost beetle
	Coleoptera: Melolonthinae	-	2	2	Grassgrub beetles
	Coleoptera: Scarabaeidae	-	2	2	Scarab beetles
	Coleoptera	-	1	1	Beetles
	Diptera: Nerioidea	-	1	1	Flies
	Diptera: Bibionidae	-	1	1	Flies
	Diptera	-	2	2	Flies
*	Hemiptera: *Dindymus versicolor*	1	-	1	Plant bug
	Hemiptera: Pentatomidae	-	1	1	Plant bug
*	Hymenoptera: *Ophelimus* spp.	2	2	4	*Eucalyptus* leaf galls
	Hymenoptera: Formicidae	1	-	1	Ants
	Hymenoptera: Psyllidae	-	1	1	Plant pests
	Isopoda	1	-	1	Slaters
	Isoptera	-	1	1	Termites
	Lepidoptera: *Agrotis* sp.	-	1	1	Greasy cutworm
	Lepidoptera: *Mythimna separata*	-	1	1	New Zealand resident moth
	Lepidoptera: *Phyllonorycter messaniella*	-	1	1	Oak leaf miner
	Lepidoptera: Noctuidae	-	1	1	Moths
	Lepidoptera	-	4	4	Moths
	Orthoptera	-	1	1	Crickets
	Insects: unidentified	4	3	7	
	Total	**18**	**32**	**50**	
	III. PLANTS				
	(a) Plant Parts				
	Allium cepa	-	-	1	Onion bulb
	Allium sativum	-	-	1	Garlic clove
	Acacia spp.	-	-	14	Leaves, phyllodes and twigs
	Acer spp.	-	-	5	Leaves and twigs
	Alnus sp.	-	-	1	Leaves and twigs
	Asparagus officinalis	-	-	2	Asparagus spears
	Bark	-		-	29 Not further identified
	Betula pendula	-	-	1	Leaves
	Bulbs	-	-	1	Liliaceous
	Casuarina spp.	-	-	7	Leaves and twigs
	Eucalyptus spp.	-	-	38	Leaves and twigs
	Foliage (Angiospermae)	-	-	69	Hardwood leaves
	Foliage (Gymnospermae)	-	-	14	Coniferous needles
	Grevilea spp.	-	-	1	Leaves and twigs
	Plant debris	-	-	2	Not further identifiable
	Poaceae	-	-	14	Grass leaves
	Quercus spp.	-	-	4	Leaves and twigs
	Sawdust	-	-	2	Not further identifiable
	Straw	-	-	4	Not further identifiable
	Timber	-	-	8	Small pieces of sawn timber
	Twig	-	-	6	Not further identified
	Ulmus sp.	-	-	1	Leaves and twigs
	Wood	-	-	11	Small chunks, not sawn
	Wood chips	-	-	1	Not further identified
	Wood shavings	-	-	1	Not further identified
	Total			**238**	

Contaminant	Number Live	Dead	Total	Notes
(b) Seed and Fruit				
Cajanus cajan	-	-	1	Pigeon pea pods
Capsicum annum	-	-	1	Green pepper fruit
Capsules	-	-	2	Not further identified
Catkins	-	-	1	*Alnus*?
Citrus spp.	-	-	2	Fruit peel
Coconut shell and copra	-	-	1	Dried
Cucurbita pepo	-	-	1	Courgette fruit (squashed)
Dried fruit	-	-	1	Not further identified
Flowers	-	-	1	Dried
Husk	-	-	1	Dried
Leguminous pods	-	-	2	Not further identified
Oryza sativa	-	-	1	Rice grains
Phaseolus spp.	-	-	7	Bean pods
Pisum sativum	-	-	1	Pea pods
Seed	-	-	13	Not further identified
Total			**36**	
IV. MISCELLANEOUS				
(a) Animal Origin				
Bird manure	-	-	1	
Feathers	-	-	3	
Spider web	-	-	1	
Total			**5**	
(b) Plant Products				
Cardboard	-	-	1	
Thread	-	-	1	
Total			**2**	
(c) Mineral or Organic Material				
Aluminium oxide	-	-	1	
Cigarette butt	-	-	3	
Debris	-	-	44	
Filter tip	-	-	1	
Gravel	-	-	3	
Grit	-	-	2	
Indeterminate	-	-	1	
Potting mix	-	-	1	
Polystyrene beads	-	-	1	
Rubber beads	-	-	1	
Sand	-	-	8	
Silt	-	-	1	
Soil	-	-	35	
Stones	-	-	1	
Water ponding	-	-	3	
Total			**106**	