FRASER RIVER ACTION PLAN

Mushroom Waste Management Project. Liquid Waste Management - Phase I & Phase II

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MUSHROOM WASTE MANAGEMENT PROJECT
LIQUID WASTE MANAGEMENT

PHASE I: AUDIT OF CURRENT PRACTICE

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Disclaimer

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1.0 INTRODUCTION

The Mushroom Waste Management Project (MWMP) was initiated by Environment Canada, the BC Ministry of Environment, Parks and Lands and the BC Ministry of Agriculture, Fisheries and Food (BCMAFF) in May 1995. The overall objective of the project is to further develop guidelines for the environmentally sound management of solid and liquid wastes generated at mushroom producing facilities. Environmental guidelines for Mushroom producers have been produced and distributed (BCMAFF 1994) in which some direction was provided for the disposal of barn wash water and contaminated storm water. Further to those guidelines the BCMAFF has proposed that the mushroom barn wash waters be collected and treated within holding tanks prior to discharge to land through drain fields. However, knowledge of the quality and treatment requirements of barn wash water is currently limited, and a sound basis for drain field design is lacking. Further complicating the situation is an apparent, but unquantified, variability in the day to day production practices between the many mushroom producers.

As part of the MWMP, research into the quality of barn wash waters and the role of drain fields in the discharge of these waters, has been commenced by the Environmental Engineering Group, Department of Civil Engineering, at the University of British Columbia.

2.0 SCOPE OF WORK

The UBC investigation is being performed in several Phases. Phase I consists of an audit of current practice and the collection and analysis of wash water samples from several facilities. Phase II will consist of an evaluation of the range of soil and groundwater regimes associated with the mushroom farms in the region, the characteristics and behaviour of identified pesticides and a desk evaluation to predict the potential fate of the wash waters on discharge to land via drain fields. Additional work may be needed depending on the evaluated results from Phase II. Phase III would consist of a long-term laboratory or field based study to investigate actual fate of the wash waters during land discharge. Phase IV would consist of the development of specific guidelines for drain field design and construction.

This Report presents the findings of the Phase I work and includes a brief description of the mushroom production process; the intra-farm variability in the production process; and the obtained data on wash water quality.

2.1 Methodology

The Phase I work consisted of the following:

1) A Review of literature on commercial mushroom production, and collection of information on the extent of local production.

2) Site inspection of six farms, and meeting with producers, to observe mushroom production and to discuss chemical usage, wash water generation and discharge.

3) Sampling of wash water from the vicinity of the barns at each of the inspected farms.

4) Laboratory testing of sampled wash waters.

The report contents are structured along the same lines.

3.0 MUSHROOM PRODUCTION

3.1 State of Industry in BC

There are currently about 60 mushroom producing facilities (farms) within British Columbia, and most of these are located within the lower Fraser Valley as shown in Figure 1. Mushroom production in BC is controlled by a Mushroom Marketing Board. The producers used to be grouped on the basis of their association with two companies: Money's Mushrooms Ltd. and Pacific Fresh Mushrooms Ltd. However Pacific Fresh and Money's have merged to form a single entity. This entity collects and sells the mushrooms from the member producers. One aspect of the cooperative approach is the centralised production of mushroom compost and the subsequent distribution of the compost to the producers. Both Money's and Pacific Fresh have a single compost facility. At this time, it is not known if they will continue to do so. There is currently, however, one new producer planning on being self-sufficient with regard to compost production.

The mushroom type produced is *Agaricus bisporus*, or the common white button type mushroom. While specialty mushroom producers exist within the region, their operations are small and were not surveyed because of operational differences.

3.2 Mushroom Production Process Description

Mushroom production in the region is of the barn type, whereby cultivation and harvesting is performed in controlled indoor conditions. Each facility typically consists of a large building ("barn") containing several rooms interconnected by a corridor. Each room contains up to six stacked beds, up to 3 meters in height in which mushrooms are cultivated. Rotation of production between the several rooms allows production on a continual basis throughout the year. The production methodology is based on guidelines developed elsewhere, and there is no region specific guideline document for commercial mushroom growing in BC. In Ontario, where mushroom production occurs on a larger scale than in BC, the Ministry of Agriculture and Foods has produced two reports (Ontario, MAF 1982,1993) which describe in some detail the mushroom production process as well as chemical usage during production. The terminology used in the following summary of the mushroom production process has been derived from the contents of the two Ontario reports. This terminology is consistent with local usage.

The mushroom production process consists of the following stages:

i) Phase I: Composting (usually off farm)

ii)	Phase II:	Cook-out/composting (further composting & pasteurization)
iii)	Spawn run:	Introduction of mushroom spawn to compost
iv)	Casing:	Application of "casing" layer (e.g. peat moss/gypsum) to trigger mushroom growth from mycelium
v)	Harvesting:	Mushroom picking (typically 3 picks)
vi)	Cookout:	Pasteurization of spent compost

The centralised production of compost in BC by the two companies constitutes Stage 1, the Phase I composting. While both companies consider their compost formulation to be proprietary, the compost generally consists of wheat straw, poultry manure, and other organic amendments (such as ground soy or peanut). Money's Mushroom Ltd. also uses horse "manure" (bedding material from the race track) in its compost formulation, with the horse manure amount ranging from 0% to 40% by weight of the initial mix. On the whole, the ratio of straw to manure tends to be at least 1:1 for both compost producers.

On delivery to the individual farms, the compost is loaded onto the beds in a room readied to receive the compost. On completion of bed filling, the "cook-out" Stage 2 is commenced. The room is closed and injected with steam. The cook-out stage consists of four steps:

- i) Pre-pasteurization period
- ii) Pasteurization
- iii) Conditioning of the compost
- iv) Cool-down period

The purpose of the "cook-out" stage is to eliminate any parasitic organisms which may compete with the mushrooms; and to also continue the breakdown of the compost ingredients to produce the nutrients required by the mushrooms during growth. The "cook-out" may be performed over a few days to two or more weeks. The *pre-pasteurization* step consists of circulating air through the room in order to reduce the differences in the temperature of the compost through the room. This stage can be performed within one or so days. The *pasteurization* step consists of injecting steam into the room and maintaining the temperature at an elevated condition for 4 - 8 hours. The target temperature is 60 °C. A higher temperature is considered unfavourable, as it may result in the elimination of thermophilic bacteria and other organisms required for further breakdown of the compost. After the *pasteurization* step, the compost is conditioned by the gradual reduction of temperature to about 40 to 45 °C, while simultaneously introducing fresh air, within the room. While further breakdown of the compost occurs, the primary objective of the *conditioning* step appears to be the volatilization and clearing of ammonia generated from the beds. The *conditioning* step is considered to be complete in the absence of ammonia odour within the room. After conditioning, the *cool-down* step consists of lowering the room temperature to 20 to 25 °C. This lowering may be accomplished within one day.

After the cook-out stage has been completed, the compost is ready for spawning (seeding with spores). Mushroom spawn is spread over the beds, and may be worked into the compost manually, or with the aid of a "spawning machine" which roto-tills the compost within each bed. After introduction and working in of the spawn, the beds are covered with a thin layer of plastic or paper to minimize moisture loss during spawn growth. Spawn growth in this manner is allowed for two weeks or so, until mycelium colonization of the compost has been achieved. This is evidenced by a white coating over most of the bed surface.

In order to trigger mushroom pinning from the spawned compost, a casing layer is applied (thin soil layer). The material used for this casing may be naturally formed topsoil, or prepared using peat moss and gypsum. Within a week or so of casing application, the mycelium will reach the surface. The "pinning" (generative stage of mushrooms) can then be induced by changing growing conditions in this case by lowering the bed temperature on introduction of fresh air into the room. After initiation of pinning, mushrooms grow in flushes. Typically, the first three flushes are picked over a period of several weeks.

After the completion of harvesting, the room is "steamed-off' at a temperature of 70°C or so for several hours in order to eliminate any diseases or biological activity prior to removal of the spent compost bed material and room washing. This is the 6th and final stage of production.

3.3 Chemical Usage

Chemical usage aimed at insect and disease control occurs during several stages of the mushroom production. A discussion of specific chemical usage is presented later in this report.

3.4 Water Usage and Discharge

Water usage within the barn during mushroom production includes irrigation of beds, steam injection, and washing of rooms and corridor. Runoff is produced during all these stages. While much of the bed irrigation water is absorbed by the compost and growing mushrooms, drippage from the beds to the floor, and subsequent runoff, does occur. Condensate from the injected steam develops on the walls and ceiling of the room, and can occur in sufficient quantity to produce runoff. The runoff from the barns can contain various constituents as a consequence of the chemical usage in the rooms and corridors and the entrainment of compost and mushrooms from incidental but recurring spillage.

Figure 2 shows the three sources of water runoff from a typical mushroom producing facility. Water runoff originates from within the barn, from the loading pad (typically paved) adjacent to the barn, and from the roof drainage and pad runoff from precipitation are ideally separated from barn runoff and pad wash water.

4.0 DETAILS OF SITE INSPECTIONS

4.1 Site Locations

Six farms were inspected and monitored as part of Phase I work. The farms are identified as (A) through (F). All of the farms consist of a barn, or barns, with paved loading pads adjacent to the rooms. Beyond this, however, the sites vary in their age; the condition of the facilities; specific chemical usage; water usage; and discharge of wash waters.

Farms (A) and (F) have relatively new (less than 3 years old) barns with up to 20 large (tall) rooms. Farm (A) has a waste water handling installation that reflects the BCMAFF proposed system of holding tanks and a tile field. Farms (B) through (E) are at least 15 years old, and have both smaller and fewer rooms, typically 10-12. The older farms are not as well configured for control of the pad and barn wash waters.

All of the inspected farms produce mushrooms as described earlier in this report.

4.2 Chemical Usage

Pesticides were applied during the latter 4 stages, Stages 3 - 6, of mushroom production at some or all of the inspected farms. The pesticides are used to protect the mushrooms against insect and fungal attack. Formalin is routinely used as a general disinfectant for house keeping, shoes and tool cleaning.

A variety of chemicals are used at each of the farms. Chemical usages which are common to all are the fungicides, Formalin and Benlate and the insecticide Baygon. Four farms reported the use of the insecticides Diazinon and APEX. The farms reported their chemical usage on the basis of brand names. Presented in Table 1 is a listing of the active ingredients, class of pesticide and chemical type along with the number of farms using a particular chemical. Details of pesticide usage at the farms as it relates to the stage of production is presented in Table 2.

The quantity of chemical usage varies between farms, and to some extent this is due to a variability in the total production bed area, and room size.

4.3 Wash Water Generation & Discharge

Wash water is generated from the loading pads, and from within the barns at all the farms with one exception. At Farm B, the rooms are not washed as part of the growing cycle, the rooms are swept only.

While barn (room and corridor) washing is to some extent a routine part of the production process, the times and frequency of washing are variable. Discussions with the producers indicate that rooms are washed not only at the end of bed loading and bed cleaning, but also at other times during production (such as after casing).

At all of the sites, wash waters are drained away from the rooms and away from the barns either via subsurface drains (farms (C), (D) and (E)), or a ditch located adjacent to the rooms (farms

(A), (B) and (F)). With the exception of farms (A) and (E), the wash water runoff is discharged to land as surface runoff.

At farm (A) the collected wash water is applied to land via a tile drain. The disposal system for this farm reflects the methodology proposed by BCMAFF. As built plans for the disposal field were not available. however the pretreatment system consists of two settling tanks of 2500 litres (600 gal.) each placed in series.

At farm (E) water collected from each room enter small individual subsurface settling pits, which are reportedly connected together by perforated pipe that is surrounded with gravel. This network eventually discharges to a gravel filled pit. The entire system is under the pavement in front of the barn.

No measurements of wash water volumes were taken at the farms as part of this Phase I work. Based on discussions with the producers, and observation of production practices, it is concluded that the quantity of runoff generated as wash water will be highly variable between farms. Wash water runoff is generated only intermittently during any given week. For example, at farm (A), flow out of the barn was observed on only two of the five consecutive days of site visits.

During the time period of the Phase I study, BCMAFF personnel facilitated the metering of an 18 room barn. Flows were 900 litres (200 gal) per week but did not include slab water. A rough guide for wash water use is taken to be 90 litres (20 gal) of water per week per room. This does not includes steam condensate which will likely carry pesticide residues off walls nor boiler blowdown that may require disposal. The quantity of condensate will be dependent on steam flow, ventilation air flow and desired room temperature. It is likely that condensate flows could be an important source. There is considerable uncertainty on this point with some estimates suggesting that total flows could be an order of magnitude greater than the room flow estimate.

4.4 Water Sample Locations

Water samples were obtained from all six of the inspected farms. With the exception of farm (A), samples were obtained as grabs. Table 3 contains details of the sample locations and times. Samples were collected in duplicate. Grabs were taken from farms B, C and D on a single day. Farm A, E and F were sampled twice, Farm A was sampled for a five day period and then three weeks later.

The waters sampled from farms (B), (D) and (E) contained floatable solids such as straw/mushroom fragments. These were not filtered out at the time of sampling. Samples from Farm (A) are representative of effluent from a new facility utilising two settling tanks. Samples (C) and (E) are examples of room washing. Samples B, D and F contain room and pad waters.

Presented in Table 4 is a summary of the analyses performed on the collected samples. The initial sampling, samples 1 - 20, included the analysis of a standard Organo-phosphate and Organo-chloride suite, however, these results did not as it was later determined include a number of pesticides normally used in this industry. As a consequence a second sampling at 3 farms (A), (E) and (F) was undertaken.

Farm B wash waters were not analyzed for pesticides in order that a second set of samples could be analyzed for Farm A.

Formalin was not analyzed for during these samplings due to a methodology problem. Formalin values will be provided in the Phase II report. Analytical methodologies are summarized in Table 5.

5.0 RESULTS OF LABORATORY TESTING

The conventional chemical results are presented in Table 6. There is an obvious difference between the effluent passing through the settling tanks, (considered treated), of Farm A, and the unsettled barn effluents of Farms B to F, with respect to total solids and the organic related constituents; BOD, COD and TOC. The COD and TOC of the treated samples are typically 10 to 20 % of the untreated samples. On the other hand, there is little change with respect to the organic carbon, nitrogen compounds, chloride or faecal coliform. On a gross basis, the untreated samples resemble a weak sewage. Of particular note is the presence of high faecal and total coliform concentrations. While these do not necessarily correlate with the presence of pathogens, these numbers have to be considered significant.

The results from farm A collected over 5 days are remarkably consistent and give some confidence of their reproducibility. In general, the duplicate samples from the other 5 farms are of the same order as the samples between the farms for most constituents. The exception are total solids, bacteria and ammonia. There is however no apparent relationship between solids and either the concentration of ammonia or bacteria numbers.

The pesticide results are presented in Table 7, 8 and 9. Table 7 shows the results of the first Organo-P pesticide scan performed on the samples. Presented in this table are the concentrations of the identified pesticides as well as an indication as to whether or not the farmer reported using the pesticide. All the pesticides in this table are found in low concentrations. The pesticides identified to be present in the washwater but not reported by the farmer may potentially be found in the formulation of a reported pesticide. These unreported pesticides may also be due to residue on materials used in the preparation of mushroom composte. In this group, phorate was the pesticide most consistently found. No chlorinated organic pesticides were found.

Diazinon was found in every washwater tested although in the fraction of parts per billion except for Farm C where it was reported at 17.6 parts per million. This is elevated level is not considered to be representative of a composite washwater, but is indicative of concentrations that can occur in a room washwater following spraying.

Table 8 presents the results of the analysis for pesticides reportedly used but which fall outside the normal Organo-P scan. Table 9 presents the results of the standard Organo-P scan performed on subsequently collected samples from selected farms and is for comparison with Table 7 results. No diazinon was found during the second set of sampling. The pesticides found at the highest levels were Baygon (propoxur) and Benlate (benomyl) which is consistent with usage. Apex was found at much lower levels or not at all although used at comparable mixed strengths.

The data does not suggest that the treated water, Farm A, was any lower in pesticides.

6.0 CONCLUSIONS

1) The generation of wash water by mushroom farms is highly variable. It is generally considered to be about 90 litres (20 gal) per room per week. This quantity does not recognize condensate generated flows or boiler blow down. There is still considerable uncertainty on total flows with some suggestions that the flows could be as much as ten times this room estimate.

2) Several pesticides are routinely used by farm operators during the mushroom growing cycle. The rate of application and frequency are highly variable and are usually based on operator preference and experience. The purpose of most of the pesticides is to protect the crop from flies. However formalin and benomyl, fungicides, were used on every farm.

3) Pesticides residues have been found in the wash water from all farms. Several pesticides such as diazinon, were found in the fraction of parts per billion (ppb) range, however chemicals such as propoxur and benomyl were found in the hundred of parts per billion range.

4) The wash water has the characteristics of dilute sewage with the treated water showing significantly lower solids, COD, BOD and TOC concentrations.

5) All of the wash waters have significant levels of total and faecal coliform.

6) Settling of the barn wash waters did not affect the pesticide concentration relative to level seen in untreated barn wash waters.

7.0 REFERENCES

APHA "Standard Methods for the Examination of Water and Wastewater", 19th Edition, Washington, D.C., 1995.

BCMAFF "Environmental Guidelines for Mushroom Producers in British Columbia", 1994.

Lachat Inc., "Lachat Methods Manual for the Quikchem Automated Ion Analyzer", 1987, 1988, 1990.

Ontario MAF, "Commercial Mushroom Growing", Pub. 350, Revised 1982.

Ontario MAF, "Ontario Mushroom Pesticide Recommendations", Pub 367, Revised Jan. 1993.

8.0 FIGURES

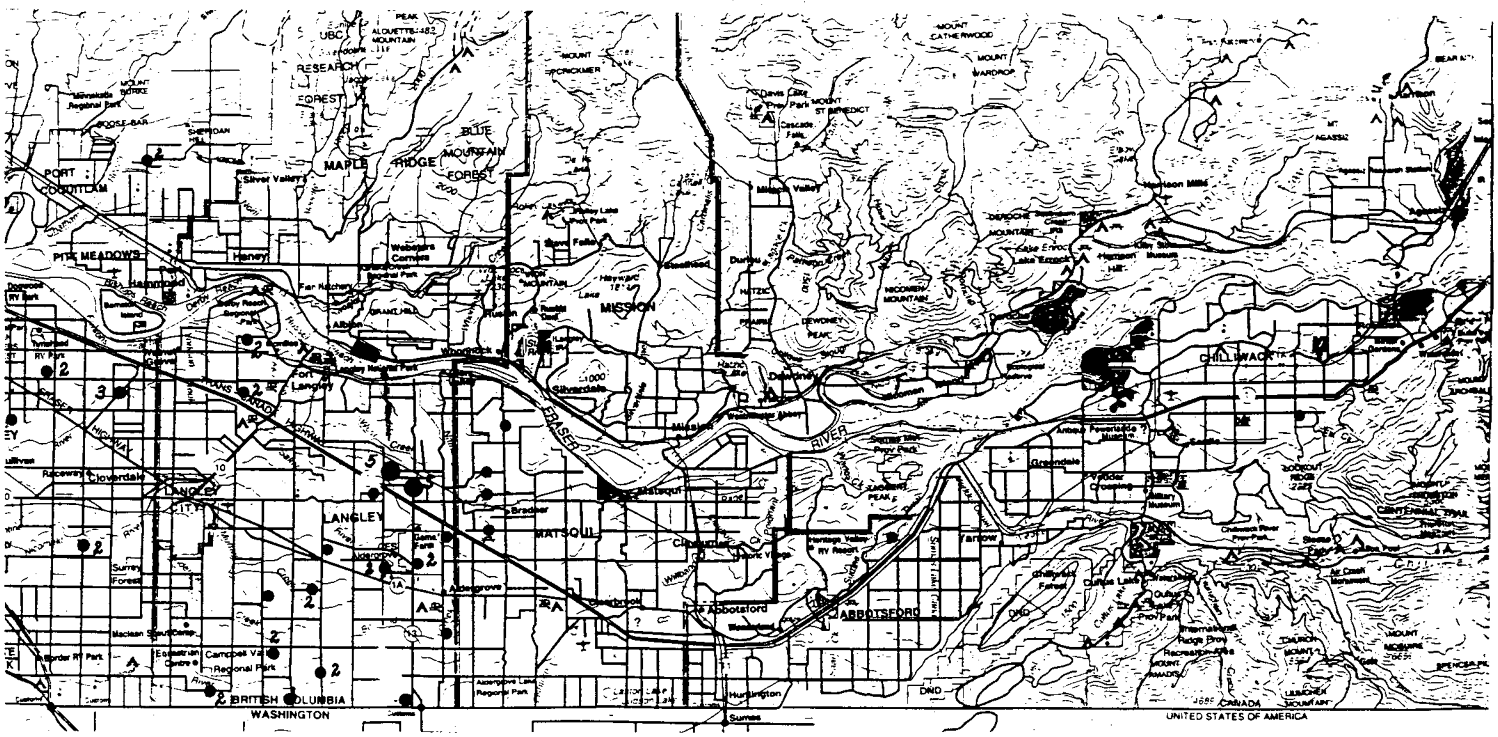

Figure 1. Mushroom Farm Locations - Fraser Valley Only.

● **4 number of farms in general local.**

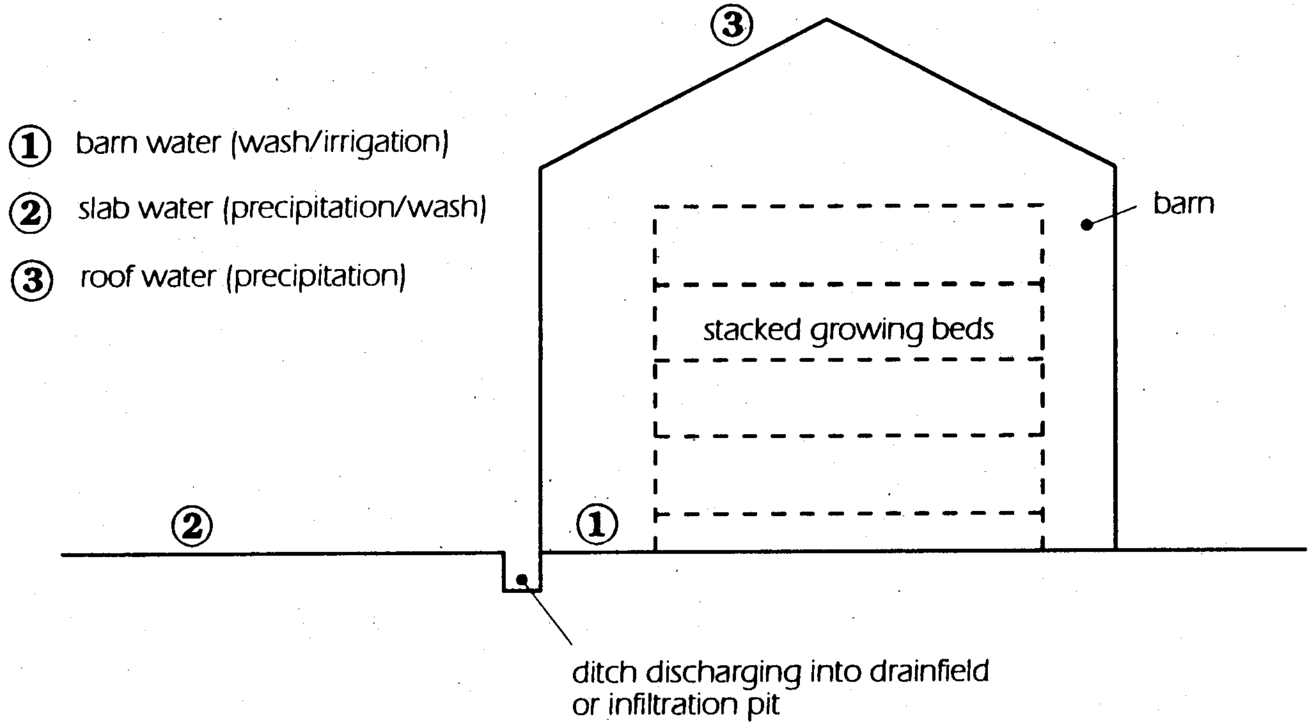

Figure 2. Schematic of Mushroom Barn Wastewater Sources.

9.0 TABLES

TABLE 1:

General Chemical Usage, Active Ingredient, Pesticide Type

Product	Active Ingredient	Class	Type	No. of Samples Farms Where Used -/6
Advance 12	sodium hypochlorite	inorganic	bactericide	1/6
Ambush	permethrim	pyrethroid	insecticide	1/6
Apex	methoprene	organic growth regulator	insecticide	4/6
Baygon	propoxur	carbamate	insecticide	6/6
Benlate	benomyl	benzimidazoles	systemic fungacide	6/6
Diazinon	diazinon	organophosphate	insecticide	4/6
Formalin	formaldehyde	organic	fungacide	6/6
Malathion	malathion	organophosphate	insecticide	3/6
Mushroom Fly Dust/ Fly Dust	malathion pyrethrin	organophosphate plant derivative	insecticide insecticide	2/6 2/6
Zineb	zineb	carbamate	fungacide	1/6

TABLE 2:
Chemical Usage During Production Stages

	Stage	Stage	Types of Chemicals Used (No. of Surveyed Farms where used)
i)	Phase I Composting	2 weeks	No chemicals used (6)
ii)	Phase 2 Cook out	10 days	No chemicals used (6)
iii)	Spawn run	10 -12 days	On soil: Apex+Benlate (1) Benlate (1) No Chemicals used (4) On walls[a]: Baygon (3) No chemicals used (3)
iii)	Casing	10 days	During formulation of casing material: Formalin (4) No Chemicals used (2) On soil: Apex+Benlate (4) Benlate (1) Formalin (1)
iv)	Pinning (Shocking)	10 days	In room[b]: Mushroom Fly Dust/Fly Dust (2) Ambush (1) Zineb (1) No Chemicals used (3)
v)	Picking, between picks	3 weeks	On surface of mushroom: Calcium Chloride[c] (2) On soil[d]: Advance 12 (1) Benlate (3) No Chemicals used (1)
vi)	Cook out	few hours	In steam: Formalin (2) No Chemicals used (4)
Chemicals used in the barns but outside rooms and chemicals routinely used for general maintenance and cleaning of equipment.			Baygon, Diazinon, Formalin (2) Baygon, Formalin (1) Baygon, Diazinon, Malathion (1) Diazinon, Malathion (1) Formalin (1)

[a]Soil is covered by a tarp during this operation
[b]Only used if flies are observed in room
[c]Used to prevent blotching on mushrooms
[d]Pesticide use varies depending on if files are observed in the room and the appearance of the mushrooms.

TABLE 3:
Sample Location and Dates

Farm	Sample Location	Sample No.	Dates
A	second settling tank	1, 2	95/10/25
		3, 4	95/10/26
		5, 6	95/10/27
		7, 8	95/10/28
		9, 10	95/10/29
		21	95/11/21
B	ponded water at end of concrete ditch, adjacent to barn	11, 12	95/10/05
C	settling pit, day after room washing and spraying	13, 14	95/10/05
D	settling pit at edge	15, 16	95/10/05
E	ponded wash water within room	17, 18	95/10/05
		22	95/11/21
F	settling pit at end of concrete ditch	19, 20	95/10/05
		23	95/11/21

TABLE 4:
Summary of Wash Water Analysis Performed

Sample	BOD	COD	TOC	IC	TKN	NO_3	NH_{4+}	Cl	TSS	Total Coliform	Faecal Coliform	Organo-P Pesticides	Organo-Cl Pesticides
1. A	X	X	X	X	X	X	X	X	X	X	X	X	X
2. A		X	X	X	X	X	X	X					
3. A	X	X	X	X	X	X	X	X	X	X	X	X	X
4. A		X	X	X	X	X	X	X					
5. A	X	X	X	X	X	X	X	X	X				
6. A		X	X	X	X	X	X	X					
7. A	X	X	X	X	X	X	X	X	X	X	X		
8. A		X	X	X	X	X	X	X					
9. A	X	X	X	X	X	X	X	X	X	X	X		
10. A		X	X	X	X	X	X	X					
11. B		X	X	X		X	X	X	X				
12. B	X	X	X	X		X	X	X	X	X	X		
13. C		X	X	X		X	X	X	X			X	X
14. C	X	X	X	X		X	X	X	X	X	X		
15. D		X	X	X		X	X	X	X			X	X
16. D	X	X	X	X		X	X	X	X	X	X		
17. E		X	X	X		X	X	X	X				
18. E	X	X	X	X		X	X	X	X	X	X		
19. F		X	X	X		X	X	X	X				
20. F	X	X	X	X		X	X	X	X	X	X		
21. A												X	
22. E												X	
23. F												X	

TABLE 5:
Analytical Methodology

Analysis	Methodology
BOD	Standard Methods 5201B
COD	Standard Methods 5220D
TOC	Standard Methods 5310B - Shimatzu Carbon Analyzer
IC	Standard Methods 5310B - Shimatzu Carbon Analyzer
TKN	Lachate Automated Ion Analyzer 10-107-06-20-E (1988)
NO_3	Lachate Automated Ion Analyzer 10-107-04-1-Z (1990)
NH_{4+}	Lachate Automated Ion Analyzer 10-107-06-1-Z (1990)
Cl	Lachate Automated Ion Analyzer 10-107-07-1-C (1987)
TSS	Standard Methods 2540 D
Total Coliforms	Standard Methods Membrane Filter 9222B
Faecal Coliforms	Standard Methods Membrane Filter 9222D
Organo-P Pesticides USEPA	Method 8140 - Organic solvent extrantion GC-FID
Organo-Cl Pesticides USEPA	Method 8080 - Organic solvent extrantion GC-ECD

TABLE 6:
Inorganic and Bacterial Results

Sample	BOD mg/L	COD mg/L	TOC mg/L	IC mg/L	TKN mg N/L	NO_3 mg N/L	NH_4^+ mg N/L	Cl mg/L	TSS mg/L	Total Coliform X 10^6	Faecal* Coliform X 10^6
1.	24.7	77	22.5	23.2	19.2	<0.05	10.69	46.0	41	7.7	0.18
2.		95	28.9	23.7	18.0	<0.05	10.60	46.8			
3.	24.8	61	21.0	22.0	14.8	0.07	10.11	45.6	34	54	0.34
4.		69	22.0	21.2	16.2	<0.05	10.27	44.9			
5.	23	84	31.2	19.3	17.3	1.28	10.67	53.0	39		
6.		82	36.3	20.5	17.8	1.26	10.41	54.1			
7.	16.6	71	21.0	20.8	14.8	0.33	9.22	39.5	19	46	0.58
8.		61	21.3	18.2	15.2	0.54	9.33	39.1			
9.	15.5	51	21.0	21.7	15.1	0.08	10.73	40.3	15	42	0.74
10.		56	20.3	22.9	16.2	0.08	10.67	40.2			
11.		824	64.5	42.9		0.08	11.94	33.9	1380		
12.	55.6	392	59.7	39.5		0.11	11.90	32.5	766	10.6	3.7
13.		604	156.3	38.3		0.25	1.08	19.0	44		
14.	218	588	166.1	40.7		0.31	1.05	19.1	36	3.6	0.27
15.		972	45.5	43.8		3.88	4.75	61.1	5230		
16.	61.6	957	48.3	45.8		5.83	4.48	60.7	1120	1.9	0.22
17.		649	106.3	26.3		0.16	5.58	44.4	750		
18.	85.5	532	135.6	26.6		0.14	6.29	45.3	600	17.8	1.4
19.		224	55.8	117.6		1.0	84.10	35	170		
20.	39.2	203	57.4	126.0		0.93	85.20	33.6	196	3.3	3

*** per 100ml**

TABLE 7:
Organo-Phosphate Pesticide Results
First Sampling - Standard Suite

Farm	Sample	Coumaphos mg/L	Diazinon mg/L	Malathion mg/L	Methyl Parathion mg/L	Mevinphos mg/L	Phorate mg/L	Terbufos mg/L
A	1	0.000464[NR]	0.000339[NR]	ND[RU]	ND[NR]	ND[NR]	ND[NR]	ND[RU]
A	3	ND[NR]	0.000464[NR]	ND[RU]	0.000396[NR]	ND[NR]	ND[NR]	ND[NR]
C	13	ND[NR]	17.6[*RU]	ND[NR]	0.0165[*NR]	0.0348[*NR]	0.0065[*NR]	0.0996[*NR]
D	15	ND[NR]	0.00047[RU]	ND[RU]	ND[NR]	ND[NR]	0.00209[NR]	ND[NR]
E	17	ND[NR]	0.00235[RU]	0.000332[NR]	ND[NR]	ND[NR]	0.00117[NR]	ND[NR]
F	19	ND[NR]	0.000576[RU]	0.0132[RU]	ND[NR]	ND[NR]	0.000684[NR]	ND[NR]
Detection Limit		0.00005	0.00015	0.00015	0.00015	0.00015	0.0001	0.00015

*This sample was taken in the room while pesticide spraying was occurring.
NR: Farmer did not report using during survey.
RU: Farmer reported using during survey.

TABLE 8:
Organo-Phosphate Pesticides
Second Sampling - Directed Analysis

Farm	Sample	Permethrin mg/L	Apex mg/L	Propoxur mg/L	Benomyl mg/L	Pyperonyl Butoxide mg/L	Pyrethrin mg/L
A	21	0.025[RU]	ND[RU]	0.77[RU]	0.351[RU]	ND[RU]	ND[RU]
C	22	0.035[RU]	ND[RU]	0.13[RU]	0.11[RU]	ND[NR]	ND[NR]
F	23	<0.001[NR]	0.0032[RU]	0.013[RU]	0.085[RU]	0.0053[NR]	ND[NR]
Detection Limit		0.00005	0.002	0.0002	0.0005[RU]	0.0005	0.005

NR: Farmer did not report using during survey.
RU: Farmer reported during survey.

TABLE 9:
Organo-Phosphate Pesticides
Second Sampling - Standard Suite

Farm	Sample	Coumaphos mg/L	Diazion mg/L	Melathion mg/L	Methyl Parathion mg/L	Mevinphos mg/L	Phorate mg/L	Terbufos mg/L
A	21	ND[NR]	ND[NR]	ND[RU]	ND[NR]	ND[NR]	0.00106[NR]	ND[NR]
C	22	ND[NR]	ND[RU]	ND[NR]	ND[NR]	ND[NR]	0.0012[NR]	ND[NR]
F	23	ND[NR]	ND[RU]	ND[RU]	ND[NR]	ND[NR]	0.00056[NR]	ND[NR]
Detection Limit		0.00015	0.00005	0.00015	0.00015	0.00015	0.00010	0.00015

NR: Farmer did not report using during survey.
RU: Farmer reported using during survey.

MUSHROOM WASTE MANAGEMENT PROJECT
LIQUID WASTE MANAGEMENT

PHASE II - EVALUATION OF WASTEWATER CONSTITUENT IMPACTS

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LIQUID WASTE MANAGEMENT

PHASE II
EVALUATION OF WASTEWATER CONSTITUENT IMPACTS

1. INTRODUCTION

The following report presents the results of the Phase II investigation. It outlines the range of soil and groundwater regimes associated with mushroom farms in the study area. It presents the characteristics and behaviour of pesticides identified in the Phase I report and presents the result of a desk evaluation of the potential fate of discharged wastewaters. As a carry over from the Phase I, work waste waters from 3 farms were sampled for formalin. Those results, sample locations and analytical methodology are also presented.

This work is part of the initiative undertaken by Environment Canada, BC Ministry of Agriculture, Fisheries & Foods, and the BC Ministry of Environmental Parks and Lands, to develop guidelines for the environmentally sound management of wastes generated by mushroom producers.

The data from Phase I are reported separately and the reader's attention is drawn to that report[1] to get the context for those results. The desk evaluation is focused towards a wash water disposal system utilizing twin setting tanks in series followed by subsurface disposal through a tile field.

2. METHODOLOGY

The Phase II work consisted of the following:

1) A review of the analytical laboratory analysis of the barn wash waters generated and presented in the Phase I report and a presentation of formalin results (Section 2.1).

2) A literature review of available information of the characteristics of the pesticides used and those identified in the farms surveyed.

3) A review of soil maps and other sources on the types of soils at all the mushroom producing farms.

4) The design and use of a model estimating the fate of pesticides in tile fields and direct surface discharge at different temperatures.

The Phase I Report identified the presence of 13 specific pesticides in the wash waters from different farms. A fourteenth pesticide, Zineb, a zinc carbamate fungacide, was reportedly used

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[1] Mushroom Waste Management Project, Liquid Waste Management. Phase I Audit of Current Practice

but was not analyzed for. Eleven of the identified pesticides are considered insecticides while the remaining two are classified as fungicides. The majority of the pesticides and all but one of the insecticides are organo-phosphates. However, the two materials present at the highest concentrations, Baygon (a.i. propoxur) and Benlate (a.i. benomyl) are both carbamates. It is our understanding that since the sampling was carried out the use of Baygon (a.i. propoxur) is diminishing and that dimethoate is being used instead for fly control. Dimethoate is an organo-phosphate insecticide which is more toxic but less persistant than propoxur.

Wastewater was collected from farms A, B and C, (See Phase I report for sample locations) on July 23, 1996 for formaldehyde analysis. Formalin, formaldehyde in solution, is used at all the farms as a general house keeping disinfectant, during casing production or at the time of steam out. Formaldehyde was not detected in any of the samples, with a detection limit set at 0.1 ppm. The analytical methodology consisted of extraction, derivalization to 2.4 - denetropheryl hydrazine and analysis on a GC as detailed in Barrich et al (1988). Formaldehyde results from two other samples collected by MOEPL (1993) were below a detection level of 0.15 ppm.

Organo-phosphate pesticides (OP) have been used since the early 1970s for crop protection mostly from insects. They are described as pesticides that are highly toxic and reactive but not persistent. The amount of initially unreacted pesticide disappears rapidly from the environment. (WHO, 1986) Studies indicate that the major health hazard, to humans caused by organo-phosphate insecticides is from acute exposure to high dose levels. This would occur during their manufacture, formulation and application in agriculture.

All organo-phosphate pesticides are subject to degradation yielding water soluble products that are believed to be non-toxic at all recommended applications and doses. The toxic hazard of these pesticides is therefore in the short term when compared to persistent organo-chlorine pesticides. (Derache, 1977)

Most OP pesticides are only slightly soluble in water, have high oil to water partitioning coefficients and low vapour pressure. In soil and in the aqueous environment, the persistence time and possible distribution will be influenced by temperature, light intensity and pH.

Most OP pesticides tend to sorb fairly strongly to soil surfaces, and their strong affinity for soil organic matter is indicated by rather moderate to high sorption coefficients (Koc). Both field and laboratory studies that have considered the vertical mobility of OP insecticides have generally found little leaching movement occurring in soil. The minor leaching of OP insecticides in most studies can be attributed to the short persistence that characterizes their behaviour in soil. Microbial breakdown is the major pathway for the degradation of pesticides in soil and in the environment as a whole. (Lamoureux, 1977). As a group, OP pesticides are considered non persistent and are known to be degraded by a variety of microorganisms.

Analysis of water from many locations has revealed few detections of OP insecticides in groundwater, drinking water wells and water courses. The U.S. department of Agriculture ranked the mobility of OP pesticides as low to moderate. (Chamber, 1992). At the same time, diazinon and dimethane, both organo-phosphate insecticides, were detected in the Abbotsford Aquifer (Liebcher et al., 1992), albeit below Canadian Drinking Water Guidelines.

The metabolic fate of OP pesticides is basically the same in insects, animals and plants. Uptake in insects or animals may occur through the skin, respiratory system or gastrointestinal tract. Pure OP pesticides exert their acute effects in both insects and mammals by inhibiting acetylcholinestarase in the nervous system, with subsequent accumulation of toxic levels of acetylcholine (Ach), which is a neurotransmitter (WHO 1986).

The carbamate group of pesticides are not easily grouped as to specific characteristics due to a wide range of chemical constructs. The two carbamates of major interest in this report are in two distinct groups. Baygon (a.i. propoxur) an insecticide, is a methyl carbamate derivative whereas Benlate (a.i. benomyl), a herbicide, is a benzimidazole derivative.

The carbamate insecticides such as propoxur are also thought to act on Ach system but in a manner that is more reversible than for the organo-phosphates. A carbamate fungicide such as benomyl does not affect Ach but acts on cell microtubules and on a fairly species specific basis. The majority of the carbamates are readily detoxified and relatively short-lived in aquatic and soil environments. Also, the vast majority of the breakdown products are less toxic than the original pesticides. One striking exception is carbendazim, which is a fungicide in its own right, but is also the initial degradation product of benonyl. The half-life of carbendazim in favourable abiotic and microbial conditions is in excess of 1/2 a year. In aquatic systems it has been reported as two years (WHO, 1993). Surveys of wells in the U.S., Netherlands, and Italy, found no benomyl or carbendazim in the US samples but did in 1/3 of wells samples in the European studies (WHO, 1993). Carbendazim was assumed to be present in the wastewater, but was not specifically tested.

The fate of pesticides in the environment is dependent on the properties of the compounds, the type of discharge, the hydrology of the area and climatic factors. A composite picture of the chemical and physical properties of a pesticide is essential for the determination of the potential fate and impact of that pesticide on the environment. Table 1 present a list of the pesticides and their respective solubility in water, octonol/water partitioning coefficient (Kow), vapour pressure, organic soil adsorption (Koc), the half life of the compounds in both an aquatic and soil environment. Data is also presented for carbendazim as it is the most significant metabolic product. Data is not available for all pesticides. Data is lacking with respect to fate in subsurface environs below the active soil layer; that zone in which a tile field would be constructed.

Solubility refers to the solubility product (KSP) of the parent molecule in de-ionized water at a specific temperature and pH. The vapour pressure is an index of the volatility of the parent molecule to enter the vapour state at a set temperature. Soil retention (adsorption) is the binding capacity of the pesticide molecule to soil organic matter as determined in sorption studies. Data on this point is often reported for specific soils in which case the fraction of organics in the soil may be already factored in and as such, normally should be reported as Kp. Sometimes it is not clear which it is. The Koc of the pesticide may not be the best method to determine the mobility of the pesticide since metabolites may have a different mobility than the parent compound but it is the most common reference present in the literature. It is, at best, a crude approximation of the soil retention capacity of a pesticide. Finally, the half-life of the compound under aquatic and soil conditions is presented in terms of days. This is the time required for the pesticides concentration to decrease by one half and is very site and condition specific.

There are screening tools available for categorizing pesticides as to their potential mobility. One such tool which has found recent favour is the Groundwater Ubigity Score (GUS), which was initially developed for ranking pesticides in California and is now finding wider use (Gustufson, 1993). Agriculture Canada used this score in developing a pesticide leaching priority list (McRae, 1991). The GUS is calculated from the half-life and Koc of the pesticide and/or primary metabolic product using the equation $GUS = \log LT_{50} .*(4 - \log Koc)$ where the LT_{50} is the time to a 50% disappearance in days and Koc is the partioning coafficient to soil organics in litres/kg. Pesticides with a GUS of less than 1.83 are unlikely to migrate to water supplies whereas those with scores above 2.83 are likely to migrate. Pesticides within these limits are considered transitional and mobility is very dependent on local conditions. Available GUS values (Gustufson, 1993) are also presented in Table 1. It should be noted that the two carbamates are the only pesticides that have high scores.

Table 2 can be used as a guide in interpreting the descriptive ranking (low-high) of the values of the various characteristics of the pesticides. It can be seen in Table 2 that the water solubility of all but three of the pesticides present in the barn wash water would be classified as low to very low. The exceptions are malathion, propoxur (Baygon) and mevinphos which would be classified as moderate and very high respectively. In terms of volatility (or vapour pressure), five of the compounds were classified as very low, two as low, two as moderate, one as high and two as very high. The main removal mechanism for the compounds classified as very high, (phorate and permethrin) and the one classified as high, (terbufos), would be volatilization. This removal process would be enhanced under a surface to ground discharge compared with a septic field discharge. However, during the Phase I site inspection some of the new barns utilizing a septic field system discharged the wash water to a surface ditch and then into settling tanks. Depending on the temperature and wash water flow rate during that period considerable volatilization could be achieved prior to entry into the tile field. Most of the compounds have very low to low-to-moderate soil retention characteristics according to the referenced Table, the exception is permethrin. However, even though sorption may be referred to as low, there is little overall movement of the pesticides in top soil because microbial degradation quickly breaks down the compounds.

With one exception, the half life of all of the pesticides in an aquatic discharge is considered very short. The half life within soils for all but the same pesticide, ranged from short to very short. Therefore all of the pesticides identified in the mushroom wash water (except possibly for carbendazim, but which was not tested for) are thought not to be resistant to degradation (i.e. will degrade) in an aerobic biologically active system. A significant uncertainty exists pertaining to wastewater which is injected into subsoils directly. While subsoils are not sterile, they do not have the biomass, organic content or nutrient base of an agricultural soil or surface water.

2.1 Soil Types

The soil type determined from the Canadian soil survey for selective mushroom farms are presented in Table 3. Where it was possible to assign a soil type at a specific farm site based on map positions, it was done, column 1 (see Appendix I for a cross-reference).

According to soil surveys, the soil at most of the farms consisted of fine textured glacial deposits and the drainage was usually classified as good. As such, the expectation that tile fields can be installed and work well is reasonable. However, there are ranges and it appears that there could be sites that are hydraulically tight with no or little movement; or conversely, too well drained to prevent movement of possible contaminants into the groundwater. The soil type at the different farms gives a general indication of the potential movement of wash water through the soil. Aerobic degradation in poorly draining or flooded soil would be reduced because of the presence of water in many of the soil pores. Thus there would potentially be an absence of oxygen for microbial processes. In the absence of oxygen, the degradation process would be slower and less complete.

Reports from specific boreholes investigation drilled with in the Surrey, Langley, Aldergrove and Abbotsford areas indicated that bedrock is encountered at depths greater than 5 meters. The well logs further indicated that the upmost 1 to 2 meters of these soils are comprised of sand and silt loams overlying gray clay. However, the stratigraphy is quite variable from location to location.

2.2 Contaminant Concentration Model

The concentration model used to evaluate potential contamination was a one-dimensional stepped degradation model. The water from the tile field was assumed to move vertically down to the water table and then move horizontally with no prior dilution. The pesticides are retarded by virtue of adsorption onto the soil organics and subsequent biodegradation of the adsorbed material. The subsequent concentration at any point in the receiving environment is based on dilution from added rainfall along the flow path. Depending on the receiving environment, one could argue that the model is conceptually weak, particularly with respect to arrival concentrations because no lateral dispersion resulting from mounding is recognized nor is downward vertical movement which will occur as the water moves horizontally with the addition of infiltration. In respect to the subsequent surfacing of the groundwater as a surface water the concentration in the groundwater is less of an issue than the mass in the plume since the dilution and eventual concentration afforded by the stream is dependent on the contaminant flux. In the case of the receiving environment being a well, the concentration in the groundwater is the key issue since a well withdrawal is somewhat analogous to taking a discrete sample. The model will overestimate the concentration at a well site and, therefore, the potential exposure to an individual.

2.3 Assumptions of the Model

Presented in Table 4 are the results from the model for pesticide concentrations that could conceivably arrive at a receiving environment through direct surface water or septic field discharge. The model assumes several key factors. The temperature was assumed to be 8°C. In the event that the temperature was higher, the rate of biological activity would increase and the resultant breakdown of the pesticides would also increase. The temperature of a wastewater discharge could potentially be lower during the winter months but the septic field discharge should be a reasonable approximation. The rate of groundwater flow was assumed to be 6-30 meters (20-100 ft) per year. The 30 m/year is approximately equal to the flow velocity of the Abbotsford aquifer. Of course this velocity would fluctuate depending on the season. The septic field discharge was assumed to encounter a water course or well in 1-5 years since the regulations for domestic tile field stipulate that the fields are to be placed 30 m (100 ft) from the nearest water course or well. The same, if not a more stringent design regulation, could apply in this case. The model assumed that the wash water would be diluted by a factor of twenty when it reaches a surface water course. Albeit, some groundwater springs are the initial sources of many surface water streams in the Lower Fraser Valley. This would be the effect of the wash water volume entering a small stream. Entering a larger water course would result in a larger dilution and potentially a reduced effect on the ecosystem. For the well situation a dilution of at least 10 times was assumed.

The range of organic soil content in the subsoils was taken to be 0.1 to 1%. The range of biological activity (half lifes) in an aquifer was taken to be 1/10 of to equal to the potential topsoil activity.

2.4 Characteristics of the Modeled Wash Water

Also presented in Table 4 are the non harmful Average Daily Intake (ADI) levels for pesticides for humans and 1/100 of the LC50 lethal concentration to the most sensitive aquatic receptor (fish, insect). The most sensitive receptor was also identified. For the purposes of this report, the no effect level was taken as 1/100 of LC_{50} of this most sensitive receptor. No attempt was made to determine whether the most sensitive species could be impacted under the model scenario or whether the species even existed in the study area. These concentrations should be used as a rough guide to evaluate the relative toxicity of the wastewater. The ADI observation or limitation to this analysis is based on a 10 kilogram child drinking 1 litre of water per day.

The first problem is that the non harmful concentrations used here for the most sensitive receptor is considerably lower than the detection limit for several compounds. This would render monitoring the effect of the mushroom water discharges quite difficult if there is a no effect requirement on the effluent itself.

The wash water utilized for the conceptual model consisted of a composite mix of all the Phase I samples analyzed (Table 4). It should be emphasized that the composite mix is based on a limited number of samples and farms. With the exception of diazinon, the composite wash water mix consisted of the highest measured concentration of pesticide during the Phase I laboratory analysis. The two compounds, propoxur and benomyl, which occurred at the highest concentrations; and were measured at all the farms, exhibited a wide concentration range. For propoxur the highest concentration was 40 times the lowest concentration. For benomyl the highest concentration was 5 times the lowest concentration. Two washwater samples collected by MEPL (1993) and analyzed for propoxur had concentrations of 73 and 83 ppb; which were within the range of the values reported in this study.

3. FATE OF CONTAMINANTS

3.1 Inorganic Constituents

Per the Phase I report, the barn wash water has the characteristics of weak sewage. Effluent from a treatment system consisting of two setting tanks in series (similar to the proposed BCMAFF system) was fairly consistent and significantly better, up to 1/20, than untreated wash water at the other farms in terms of solids and COD. For BOD, TOC and inorganic carbon the levels with the BCMAFF system were roughly half the untreated. No significant reductions were seen in other constituents.

There was a weak correlation between total suspended solids and COD and none for BOD or TOC. BOD and TOC correlate quite well ($R = 0.89$; $n=10$). Two possible observations can be drawn from that information; first that the solids do not appear to be readily degradable, which is not surprising given that they are likely from the compost, and secondly, that there is some BOD available to allow for the establishment of a biological mat in and around the tile field.

The long term and successful operation of tile fields treating organic and nutrient rich effluents is dependent on a balance between the establishment of a viable aerobic biological mat where most of the constituent treatment occurs and the continuous destruction of solids so that oxygen and water transfer continues to occur.

The low level of solids discharged from the twin setting tanks (Farm A) is encouraging with respect to limiting the movement of non-degradable solids into a subsurface tile field; although over the long term, solids accumulation in the tile field will have to be addressed. The low level of degradable organics in the wash water coupled with the low flows is going to limit the development of a biologically active mat which in turn may limit the treatment of organics that are not easily degraded.

For conventional constituents and assumed average flows the loading coming from a 20 room barn will be less than from a conventional single family dwelling. Nitrate-N loading from a 20 room barn should be about 1.3 kg/yr based on an average TKN concentration of 17.5 mg/λ-N, an 80% conversion to nitrate-N and a 90 litres per room-week flow. This is a relatively small contribution. The major qualifier is the assumed flow. If the assumed flow was 10 times greater, the nitrate loading of 13 kg/yr would be about 3.5 times that from a single family dwelling (500 *l*/day, 20 mg/*l* NO_3N).

3.2 Fate of Coliform Bacteria

As outlined in the Phase I report, the concentration of coliform bacteria present in the washwater was a potential concern. Since the effluent contains a high quantity of coliform bacteria, there was a potential that it also contains pathogenic bacteria. The potential for domestic discharges, which contains similar bacteria numbers, to contaminate both surface and groundwater supplies has been evaluated many times. In an extensive experiment studying 19 septic systems, researchers found that if the system was functioning properly hydraulically, they exhibited little potential hazard with respect to bacterial contamination of groundwater (Crane et al., 1989). The research determined that the biological mat which formed between the drain field trench and the soil was responsible for the greatest reductions found in septic discharges. Further studies determined that as long as the field remained unsaturated then the movement of bacteria could be limited to 1 metre. Discharges during the winter months were determine to travel up to 3 times further (Crane et al., 1984). The key in all cases is to maintain a zone of unsaturated soil under the tile field both for bacterial removal in the soil and maintenance of the biological mat.

The underlying factor for ensuring proper bacterial and organic removal is that sound engineering practices be utilized in the design and the siting of the septic field.

3.3 Fate of Pesticides

Based on the compiled information in combination with the model predicted discharge concentrations all but one of the pesticides (Phorate) are potentially of concern for a direct surface water discharge. It must be noted that the model did not take chemical reactions into account but in most cases, this would be a minor factor. In some cases the discharge maximum concentration reported was several orders of magnitude greater than the no effect concentration (1/100 of LC50) to the most sensitive receptor (see Section 2.4). The compounds of most concern in a direct aquatic discharge would be benomyl (Benlate), propoxur (Baygon) and permethrin (Ambush). Their high residual concentration identified in wash water effluent combined with the sensitivity of the ecosystem receptor is potentially of concern. Their predicted concentration is more than 3 orders of magnitude higher than the level which would not affect the most sensitive receptor. It must be emphasized that this was a desk top exercise to flag potential concerns. The potential effect of such a discharge at any one of the farms was not determined. The literature survey provided no receiving water data for the pesticides at the concentrations calculated.

The results of this simple model indicate that all the compounds would enter the water course at lower concentration when treated through a tank and tile field system than through a direct aquatic discharge. The predicted concentrations are orders of magnitude lower than a direct aquatic discharge and below the analytical detection limits used in this study (Table 4). When discharged through a tile field the pesticides are reduced through microbial degradation, hydrolysis, adsorption to soil and dilution due to rainfall. The ground discharge at worst allows the pesticides to be retained in the soil and diluted. Even the concentration of the pesticides resistant to microbial degradation would potentially be reduced in this system. Due to the slow degradation of carbendazim (benomyl metabolite assumed to be present), and propoxur could potentially enter a water course at concentrations ranging from below detection to higher than the referenced no effect level for the most sensitive receptorl.

None of the pesticides appear to arrive at drinking water wells at anything close to a human health threshold level, however, the same pesticides are calculated to be present at measureable concentrations.

The two carbamate pesticides (propoxur and benomyl) are the two problematic compounds. Carbendazim will likely persist in any groundwater regime in which it is introduced. What is not entirely obvious is whether or not it will move any significant distance from the point of introduction. The literature is contradictory in respect to partitioning between water and soil organics. Propoxur is recognized as reasonable mobile and degradable; it is the efficacy of subsoil microbial degradation that will determine if this material is a problem. Given that the proposed method of disposal is injection below the active and organic richer top soil a slower, rather than faster, degradation would be anticipated.

Very little information was discovered about the pesticide coumaphous. It was found in a low concentration at one of the farms effluent during the Phase I investigation. Due to the low concentration detected, the compound should potentially not be of concern. No comment can be made about the fungacide Zineb. Formalin because it was not detected in any of the wash water samples is not considered to be a problem.

3.4 Overview

Propoxur and benomyl are the two pesticides that along with Formalin were used in every barn and in every case were found in the barn effluents and at the highest concentrations. They are also the two pesticides which, given conservative assumptions, could contaminate groundwater off property and eventually surface waters if using a disposal method of settling tanks and tile field. Conversely that same system will provide significant reductions relative to direct surface discharges. For many of the farm locations, the soil conditions should provide for very high retention and as a consequence, low contamination risk. What is also clear is that there are soils and conditions in the Fraser Valley that will not provide high retention. There also will be situations where subsurface disposal is not feasible and an alternative treatment will have to be considered.

There is uncertainty with the soil partitioning coefficient for benomyl (carbendazim metabolite) and microbial degradation rates for propoxur which directly affect the predicted concentration. It may be worthwhile trying to refine these values for the local conditions.

4. CONCLUSIONS

1) The concentrations of pesticides should in theory be reduced several orders of magnitude through tile field soil discharge compared to a direct surface discharge. This should in most, but not all possible cases, result in a no impact situation.

2) The concentrations of permethrin, propoxur and benomyl under the modelled conditions of a direct discharge to surface waters were potentially several orders of magnitude more concentrated than the no effect level for the most sensitive receptor.

3) The potential modeled concentrations of propoxur and benomyl reaching surface waters through groundwater discharges could be in excess of no effect levels for the most sensitive receptor.

4) The concentration not harmful to the most sensitive receptor was often lower than the practical analytical detection limit. Monitoring the discharge concentration would be difficult since the discharge concentration is several orders of magnitude lower than the detection limit.

5) The tile field disposal of wash waters should provide effective treatment of bacteria.

6) Nitrate loadings to groundwater from the barn wash water will occur as a consequence of tile field disposal but at very low levels relative to most agricultural practices.

5. RECOMMENDATIONS

1) Methods be investigated for a simple treatment of propoxur and/or benomyl.

2) Biodegradation rates for propoxur be investigated under the conditions of a tile field discharge into subsoils.

3) The presence and mobility of carbendazim in mushroom barn washwater be determined.

Table 1. Characteristics of Identified Pesticides

Pesticide	Water Solubility (ppm) 20°C	Kow 20°C	Vapour Pressure (mm Hg)	Soil Adsorption Koc (ml/g) (unless other-wise indicated)	Half Life Soil 20°C (Days)	Half Life Aquatic System 20°C (Days)	GUS*
Benomyl (Benlate)[47]	4 (25°C)[43]	22.9	4×10^{-8}	K^{om}=1090 mg/g K^{oc}=1860 mg/g	silt loam 0.79[30,47]	0.83	4.03
Carbendazim [48]	8 (25°C)	30.9	4×10^{-8}	K_{α}~2000 mg/g	320	743	4.03
Diazinon[4]	40	1290[20]	6×10^{-6} [11]	1000[11]	Sand, silt Loam 14-22[2,19]	<2	1.79
Coumaphous[43]	1.5		9.8×10^{-8}		59		
Malathion[4]	144	560[43]	4×10^{-5}	1800[11]	0.247[10,16,26,31]	<2[40,41,42,47]	0.0
Methoprene (Apex)[43]	1.4		2.8×10^{-5}				
Methyl Parathion[46]	12	478[43]	4×10^{-5}	4800	Muck 11[1,26,46]		0.36
Mevinphos[11]	6×10^{5}		3×10^{-9}	40[3]	sand, silt 0.5 hrs[4,10,26,32]	3[32]	1.91
Permethrin[43]	0.2 (30C)	$1.2X10^{6}$	1.3×10^{-3}	Little movement [45]	Sand, clay, silt <28[45,12]	0.25-1[45]	-1.29
Phorate[47]	50	8410	1.9×10^{-3}	750	Silt, sand clay loam 7-9[27,33,34,47]	0.0241	1.19
Piperonyl Butoxide[47]		56200	8.8×10^{-7}		resistant		
Propoxur (Baygon)[28]	1950	37-236	6.5×10^{-6}	25-44%	most soils 9-25	2.3	3.73
Pyrethrin[47]	Virtually insoluble in water	Very low			rapidly degraded	Readily oxidized in sunlight	
Terbufous[15,47]	6	33000	3×10^{-4}	842	Abbotsford soil 15.4[37,38,39]	<3[9]	0.57

*From Gustufson, 1993. Half life and Koc values used to calculate GUS may differ from those presented in this table.

Table 2: Interpretation of the Relative Characteristics of Pesticides
(Chambers 1992)

Descriptive terminology	Water Solubility (ppm)	Vapour Pressure (mm Hg)	Soil reactivity (Koc)	Half Life (Days)
Very low, very short	<10	$<1X10^{-6}$	100	<10
Low, short	10-100	$1\text{-}10X10^{-6}$	100-1000	10-30
Moderate	100-1000	$1\text{-}10X10^{-5}$	1000-10000	30-90
High or long	1000-10000	$1\text{-}10X10^{-4}$	10000-100000	90-180

Table 3: Range of Soil Types for Representative Mushroom Farms in the Fraser Valley.

Farm Number	Soil Code	Main Soil Type[14,22,23,36]	Drainage	Secondary Soil Type
2	W-AB/(C-bc,So-1)	Whatcom- Moderately fine texture glacial deposits.	Moderately well, telluric seepage	Albion- Moderately fine to fine textured glaciomarine deposits
5,42	W/bc, W/DE	Whatcom- Moderately fine texture glacial deposits.	Moderately well, telluric seepage	
7,44	V-RC/ab	Vinod- 10-40 cm of organic material over moderately fine textured deltaic deposits	Very poor, high ground water table	Richmond- 40-160 cm of well-decomposed organic material over moderately fine textured deltaic deposits (same drainage)
12,15	W/ec	Whatcom- Moderately fine texture glacial deposits.	Moderately well, telluric seepage	
14,22	W-SC-N/c	Whatcom- Moderately fine texture glacial deposits.	Moderately well, telluric seepage	Scat- Moderately fine textured glaciomarine deposits (poor drainage, perched water table)
20	W-SC/(cd,So-1)	Whatcom- Moderately fine texture glacial deposits.	Moderately well, telluric seepage	Scat- Moderately fine textured glaciomarine deposits (poor drainage, perched water table)
23	W-SC/(dc,So-1)	Whatcom- Moderately fine texture glacial deposits.	Moderately well, telluric seepage	Scat- Moderately fine textured glaciomarine deposits (poor drainage, perched water table)
25,35	N-SC/d	Nicholson- Moderately fine textured glaciomarine deposits	Moderately well	Scat- Moderately fine textured glaciomarine deposits (poor drainage, perched water table)
31	SS/BC	Sunshine- Sandy littoral and glacial outwash deposits	Imperfect, perched water table	
37	N-AB/cb	Nicholson- Moderately fine textured glaciomarine deposits	Moderately well	Albion- Moderately fine to fine textured glaciomarine deposits
40	MH/b	Marble Hill- More than 50 cm of medium textured eolian deposits over gravelly glacial outwash deposits	Well	
48	SS/DC	Sunshine- Sandy littoral and glacial outwash deposits	Imperfect, perched water table	
50	W-AB/bc, SS/cb,s1	Whatcom- Moderately	Moderately well,	Albion-

		fine texture glacial deposits.	telluric seepage	Moderately fine to fine textured glaciomarine deposits
53	W-SC/(dc,So-1)	Whatcom- Moderately fine texture glacial deposits.	Moderately well, telluric seepage	Scat- Moderately fine textured glaciomarine deposits (poor drainage, perched water table)
54	CD/b	Cloverdale- Moderately fine to fine textured marine deposits	Poor; perched water table	
56	SS-HN/c	Sunshine- Sandy littoral and glacial outwash deposits	Imperfect, perched water table	Heron - Coarse textured littoral deposits over moderately coarse textured glacial till or moderately fine textured glaciomarine deposits (poor; perched water table)
59	W-HN-SC/cb	Whatcom- Moderately fine texture glacial deposits.	Moderately well, telluric seepage	Heron - Coarse textured littoral deposits over moderately coarse textured glacial till or moderately fine textured glaciomarine deposits (poor; perched water table)
60	W-AB/bc	Whatcom- Moderately fine texture glacial deposits.	Moderately well, telluric seepage	Albion- Moderately fine to fine textured glaciomarine deposits

Table 4: Model Predicted Concentrations of Mushroom Farm Effluent Contaminants via Direct Discharge or a Septic Field Discharge, and Comparative Environmental Criteria.

Pesticide	Maximum concentration observed during Phase I (ppm) (wastewater composite mix)	Average daily non-harmful intake For man (mg/Kg)[43]	Average daily non-harmful intake concentration - 1 litre/day for 10 kilo child mg/l	1/100 LC50 conc. of most sensitive receptor (ppb)[7,13,18,24,35,43,44,45,46,47]	Estimated concentration through direct aquatic discharge @ 8°C and 20:1 dilution (ppb)	Estimated concentration leaving tile field discharge @ 8°C and 20:1 dilution (ppb)	Estimated concentration at a well through tile field dis-charge @ 8°C ppm 10:1 dilution range	Analytical detection limit (ppb)	LC50 (ppb)
Benomyl (Benlate)	0.351	0.2	2.0	0.06 yolk sac fry channel catfish	**<u>17.6</u>**	ND	ND	0.5	6
Carbendazim	Not tested	0.2	2.0	0.06*	**<u>17.6</u>**	**ND** 3.1	ND to **<u>6.2</u>**	5.8	1750
Coumaphous	0.000464	0.6	6.0					.35	-
Diazinon	0.00235	0.04	0.4	0.08 water flea	**0.12**	ND	ND	0.05	8
Malathion	0.0132	0.4	4.0	0.07 honey bee	**0.66**	ND	ND	0.15	7.1
Methoprene (Apex)	0.0032	0.04	20.0	0.05 larval fly	ND ! to (**<u>0.16</u>**)	ND	ND	2.0	5
Methyl Parathion	0.0165	0.04	0.4	0.005 mosquito larvae and water flea	ND	ND	ND	0.15	0.5
Mevinphos	0.0348	0.03	0.3	0.013 river trout minnow	ND to (**<u>0.017</u>**)	ND	ND	0.15	1.3
Permethrin (Ambush)	0.035	0.1	1.0	0.0002 stone crab	**1.75**	ND	ND	0.05	0.2
Phorate	0.0065	0.004	0.04	0.013 river trout minnow	ND to (**<u>0.6</u>**)	ND	ND	0.1	1.3
Piperonyl Butoxide	0.0053	0.6	6.0	0.53 carp minnow	0.25	ND	ND	0.5	53
Propoxur (Baygon)	0.77	0.4	4.0	0.02 larval blackfly 3.7 water flea	**38.5**	ND to **1.0**	ND to **2.0**	0.2	2
Pyrethrin	< 0.005	0.6	6.0	0.015 honey bee	**0.25**	-Readily oxidized in sunlight -rapidly degraded	ND	5.0	1.5
Terbufos	0.0996	0.004	0.04	0.04 bluegill	0.05	ND	ND	0.15	4

assume same limits as for Benomyl* *!*** *number in bracket is estimated concentration but is below analytical detection limit.*

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7. APPENDIX I

Farm #	Location	Soil Type
2.	30 Ave. & 224 St. Langley	W-AB/C-be S 0-1
5.	82 Ave. & 218 St. Langley	W/bc, W/DE
7.	39 Ave. & 176 St. Surrey	V RC/ab
12.	62 Ave. & 264 St. Aldergrove	W/ec
14.	63 Ave. & 256 St. Aldergrove	W-SC-N/c
15.	60 Ave. & 264 St. Aldergrove	W/ec
20.	39 Ave. & 256 St. Aldergrove	W-SC/(cd, 50-1)
22.	65 Ave. & 256 St. Aldergrove	W-SC-N/c
23.	48 Ave. & 274 St. Aldergrove	W-SC/(dc, 50-1)
25.	64 Ave. & 261 St. Aldergrove	N-SC/d
31.	88 Ave. & 186 St. Aldergrove	SS/BC
35	64 Ave. & 261 St. Aldergrove	N-SC/d
37	59 Ave. & 264 St. Aldergrove	N-AB/cb
40.	82 Ave. & 140 St. Surrey	MH/6
42.	82 Ave. & 217 St. Langley	W/bc W/DE
44.	38 Ave. & 176 St. Surrey	V-RC/ab
48.	88 Ave. & 166 St. Surrey	SS/DC
50	32 Ave. & 238 St. Langley	W-AB/6c
		SS/cb, sl
53.	58 Ave. & 266 St. Aldergrove	W-SC/(de, 50-1)
54.	80 Ave. & 181 St. Langley	CD/b
56.	40 Ave. & 264 St. Aldergrove	SS-HN/c

59.	36 Ave. & 264 St. Aldergrove	W-HN-Sc/cb
60.	36 Ave. & 261 St. Aldergrove	W-AB/bc