

**FRASER RIVER  
ACTION PLAN**



**Biosolid  
Stabilization  
Demonstration  
Project**



**Canada**

**DOE FRAP 1998-06**



Environment  
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# **BIOSOLID STABILIZATION DEMONSTRATION PROJECT**

DOE FRAP 1998-06

Prepared for:

Environment Canada  
Environmental Protection  
Fraser Pollution Abatement  
North Vancouver, B.C.

Prepared by:

Ian Shand and Associates Inc.

March 1998

## **DISCLAIMER**

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# **BIOSOLID STABILIZATION DEMONSTRATION PROJECT**

## **Final Report**

(Submitted by Ian Shand and Associates, March 1998)

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## SUMMARY

The project was supervised by Ian Shand and Associates. The work was done with the Cooperation of the Chemical Lime Co. of Canada (CLC) and the Pacific Agri-Food Research Centre (PARC), Agassiz. Process effectiveness and soil and crop response were measured through the joint efforts of the three parties.

The project was designed to test the effectiveness of a lime pasteurization process to partially dehydrate and stabilize various high moisture organic wastes generated in the Fraser River Basin. The project also assessed the effectiveness of the resulting treated wastes as soil conditioners and as sources of nutrients (N,P and K), and evaluated parameters associates with lime pasteurization. The project had four objectives, viz. (a) to demonstrate the process to interested parties and a wide range of potential users; (b) to use several organic waste materials (these were aerobic and anaerobic digested sludges (biosolids) from municipal wastewater treatment plants, dairy cattle slurry, fish offal , and poultry layer manure) in order to establish the level of lime addition needed to raise the temperature of the lime-treated materials to pasteurizing temperature (63-66°C for 30 minutes or 72°C for 15 seconds) (Bender, 1975); (c) to measure ammonia emission in these lime-treated materials over a wide range of levels of lime addition and to measure coliform content and various physical and chemical parameters of these products; and (d) to measure the liming and nutrient value of the resulting lime-treated materials for application to soils.

There were three demonstrations, all with the mobile lime treatment plant of the CLC. The first demonstration, of lime treatment of anaerobic digested sludge at the District of Chilliwack waste water treatment plant (WWTP), took place on 13th November, 1996. A demonstration of lime treatment of aerobic sludge at the District of Kent WWTP took place on 14th November, 1996. A demonstration of lime treatment of PARC dairy cattle manure (barn floor scrapings), PARC layer manure and commercial fish offal took place on 28th November, 1996. A wide range of parties from government and private industry attended.

Small scale tests were then conducted on the fish offal, dairy manure, poultry manure Chilliwack biosolids and Kent biosolids. The relationship between lime concentration and temperature (on all except the Kent biosolids) was determined by mixing the lime and organic materials in a mortar mixer and then transferring to 44 imperial gallon steel drums. It was established that the concentration of lime to add to the various waste materials for pasteurization was 15 to 20% for the Chilliwack biosolids, 20% for the poultry manure and 30% for each of the other materials.

Further tests for measuring the relationship between ammonia emissions and time were conducted on a laboratory scale over 168 hours. For the biosolids, ammonia emissions increased dramatically for the first 24 hours as a result of lime treatment. Over the remainder of the 168-hour test period, the emissions were approximately the same as for the untreated materials. For fish offal the ammonia emission was increased by 60% for the first 24 hours, and thereafter virtually ceased, whereas the untreated material

continued to produce ammonia at a rate only slightly lower than that for the first 24 hours. These differences were attributed to microbial activity. For dairy cattle slurry, lime treatment had little effect on ammonia emission, but for poultry slurry, initial emission during the first 24 hours increased approx. four-fold and then became negligible, whereas the emissions from the untreated material continued at a high level.

In summary, these results show that lime increases the emission of ammonia in the first 24 hours (although the increase for dairy cattle manure was not substantial), thereby suggesting the value of an ammonia scrubber during processing. This ammonia could be used as a chemical fertilizer separately or added back to the treated material. Nutrients could be added to the treated organic material to make a complete customized fertilizer as is already being done in Belgium (Chemical Lime Co. 1998). The pasteurization virtually eliminates ammonia emission after the first 24 hours, particularly for the fish offal and the poultry manure. A major advantage of lime treatment is that the resulting product is suitable for long-term storage at site of production, because of the virtual elimination of further chemical and microbiological reactions and the unattractiveness for vectors.

A report comparing the economics of lime stabilization, composting and thermal drying supplied by the Chemical Lime Co. (Rothberg, Tamburini and Winsor, Inc., 1996) showed lime stabilization to be the most economical. Details are presented in Appendix 3.

The laboratory investigations produced the following conclusions:

1. Because of the substantial levels of macroelements in the quicklime-treated materials, they would most likely need to be tested according to the requirements of the Fertilizer Act before being accepted as a commercial soil-amending product in Canada.
2. The products from quicklime treatment of the four organic wastes assessed in this study were all effective and relatively quick reacting soil liming agents, but would have to be added at levels 3-5 times higher than commercial liming products such as limestone because of the lower calcium carbonate equivalents of the former.
3. The products could be easily air-dried, crumbed and screened to a size and form suitable for uniform field application. There was no advantage in liming-intensity potential of the products by screening through 3 mm compared to 6.5 mm screens.
4. The products contained variable amounts of nutrients essential for plants. If these products were to be used at soil-liming rates, the levels and composition of complementary fertilizers would have to be adjusted to maximize the value of these nutrients and minimize the possibility of excessive total levels of their application. The total level of phosphorus application should be given special attention.
5. The lime treated product from municipal sludge biosolids, which contained substantial concentrations of non-nutrient metals, would need to be given special attention with



regard to excessive soil accumulation, especially for mercury, lead and cadmium, but only if this product were to be considered for high levels of application on any one area for an extended period.

6. Two tests for measuring the speed of the pH adjustment (back titration after treatment with either EDTA or oxalate) were found to be satisfactory .

## RÉSUMÉ

Le projet a été réalisé sous la surveillance de l'Ian Shand and Associates. Les travaux ont été effectués avec la coopération de la Chemical Lime Co. of Canada (CLC) et de la Pacific

Agri-Food Research Centre (PARC), Agassiz. L'efficacité du procédé et la réponse des sols et des cultures ont été mesurées grâce aux efforts conjoints des trois parties ci-dessus.

On a conçu ce projet pour déterminer dans quelle mesure le processus de pasteurisation à la chaux permet de déshydrater et de stabiliser efficacement divers déchets organiques riches en humidité produits dans le bassin du fleuve Fraser. On a aussi évalué, durant le projet, l'efficacité comme amendements des sols et sources d'éléments nutritifs (N, P et K) des déchets ainsi traités et on a déterminé les paramètres associés à la pasteurisation à la chaux. On cherchait à atteindre quatre objectifs, soit : (a) faire la démonstration du procédé devant les intéressés et devant une vaste gamme d'utilisateurs potentiels; (b) utiliser plusieurs types de déchets organiques [boues digérées aérobies et anaérobies (biosolides) provenant d'usines d'épuration des eaux d'égout des municipalités, lisier de bovins laitiers, déchets de poissons et fientes de pouleuse, afin d'établir le niveau de chaulage nécessaire pour augmenter la température des matières chaulées jusqu'à la température de pasteurisation (63-66 °C pendant 30 minutes ou 72 °C pendant 15 secondes) (Bender, 1975); (c) mesurer les émissions d'ammoniac dans ces matières chaulées sur une vaste gamme de niveaux de chaulage et mesurer le taux de coliformes ainsi que divers paramètres physiques et chimiques de ces produits; et (d) mesurer le chaulage et la valeur nutritive des matières chaulées destinées à être appliquées sur les sols.

On a procédé à trois démonstrations en utilisant, chaque fois, l'usine de chaulage mobile de la CLC. La première démonstration, qui portait sur le chaulage de la boue digérée anaérobie de l'usine d'épuration des eaux usées du district de Chilliwack, a eu lieu le 13 novembre 1996. On a procédé à une démonstration du traitement à la chaux de la boue aérobie à l'usine d'épuration du district de Kent le 14 novembre 1996. Une démonstration du traitement à la chaux du fumier de bovins laitiers (déchets obtenus par raclage de planchers d'étable) de la PARC, des fientes de pouleuse de la PARC et de déchets de poissons marchands a eu lieu le 28 novembre 1996. Une vaste gamme de représentants des gouvernements et de l'industrie privée ont assisté à ces démonstrations.

Des essais à petite échelle ont ensuite été effectués sur les déchets de poissons, le lisier de bovins laitiers, les fientes de pouleuse, les biosolides de Chilliwack et les biosolides de Kent. On a déterminé la relation entre la concentration de chaux et la température (pour toutes ces matières, sauf les biosolides de Kent), en mélangeant la chaux et les matières organiques dans un malaxeur à mortier, puis en transférant le tout dans des barils en acier de 44 gallons impériaux. On a établi que la concentration de chaux nécessaire à la pasteurisation des divers déchets était de 15 - 20 % dans le cas des biosolides de

Chilliwack, de 20 % dans le cas des fientes de poudeuse et de 30 % dans le cas des autres matières.

D'autres essais destinés à déterminer la relation entre les émissions d'ammoniac et le temps ont été effectués en laboratoire sur une période de 168 heures. Dans le cas des biosolides, les émissions d'ammoniac augmentaient énormément au cours des premières 24 heures en raison du traitement à la chaux, mais demeuraient, pendant le reste de la période d'essai, à peu près au même niveau que les émissions observées avec les matières non traitées. Dans le cas des déchets de poissons, les émissions d'ammoniac augmentaient d'environ 60 % au cours des premières 24 heures, puis diminuaient essentiellement à zéro par la suite, tandis que les matières non traitées continuaient de produire de l'ammoniac à un taux qui n'était que légèrement inférieur au taux observé au cours des premières 24 heures. On a attribué ces différences à l'activité microbienne. Dans le cas du lisier de bovins laitiers, le traitement à la chaux n'avait guère d'effet sur les émissions d'ammoniac; cependant, dans le cas des fientes de poudeuse, les émissions au cours des premières 24 heures augmentaient par un facteur d'environ quatre, puis devenaient négligeables, tandis qu'elles demeuraient élevées dans le cas des matières non traitées.

En résumé, ces résultats montrent que le traitement à la chaux augmente les émissions d'ammoniac au cours des premières 24 heures (cette augmentation n'était pas importante dans le cas du lisier de bovins laitiers), ce qui laisse supposer qu'un épurateur d'ammoniac serait utile durant le traitement. Cet ammoniac pourrait être utilisé séparément comme engrais chimique ou être rajouté aux matières traitées. On pourrait ajouter des éléments nutritifs aux matières organiques traitées pour obtenir un engrais véritablement fait sur mesure, comme cela se fait déjà en Belgique (Chemical Lime Co. 1998). La pasteurisation élimine pratiquement toutes les émissions d'ammoniac après les premières 24 heures, plus particulièrement dans le cas des déchets de poissons et des fientes de poudeuse. Le traitement à la chaux possède un avantage important : le produit qu'il permet d'obtenir peut être entreposé à long terme au site de production, en raison de l'absence essentiellement complète de réactions chimiques et microbiologiques et du peu d'attrait qu'il présente pour les vecteurs.

Selon un rapport fourni par la Chemical Lime Co. (Rothberg, Tamburini et Winsor, Inc., 1996) dans lequel on comparait les aspects économiques de la stabilisation à la chaux, du compostage et du séchage thermique, c'est la stabilisation à la chaux qui est le procédé le plus économique. L'Annexe 3 renferme des précisions à cet égard.

Les études effectuées en laboratoire ont permis de tirer les conclusions suivantes :

1. Étant donné les taux élevés de macro-éléments dans les matières traitées à la chaux vive, il y aurait tout probablement lieu de soumettre ces matières à des essais conformément aux exigences de la Loi sur les engrais avant de les accepter comme amendements des sols au Canada.

2. Les produits obtenus par traitement à la chaux vive des quatre déchets organiques évalués au cours de cette étude étaient tous des agents de chaulage des sols efficaces et réagissant assez rapidement; cependant, il faudrait, en raison de leur plus faible équivalent en carbonate de calcium, les ajouter à un taux de 3 à 5 fois plus élevé que les produits de chaulage commerciaux comme le calcaire.
3. On pourrait facilement sécher les produits à l'air, les réduire en granules et les tamiser en vue d'obtenir une taille et une forme permettant de les épandre uniformément. Le tamisage sur un tamis de 3 mm au lieu d'un tamis de 6,5 mm ne présente aucun avantage sur le plan de la capacité de chaulage des produits.
4. Les produits contenaient des quantités variables d'éléments nutritifs essentiels pour les plantes. Si ces produits étaient utilisés aux taux de chaulage des sols, il faudrait ajuster les taux et la composition des engrais complémentaires pour maximiser la valeur de ces éléments nutritifs et minimiser les risques de taux totaux excessifs lors de l'application. Le taux total d'application de phosphore devrait faire l'objet d'une attention particulière.
5. Le produit traité avec un calcaire provenant de biosolides tirés de boues municipales contenant des quantités importantes de métaux non nutritifs devrait faire l'objet d'une attention spéciale, car il y aurait alors risque d'accumulation en quantités excessives de métaux dans les sols, plus particulièrement de mercure, de plomb et de cadmium, mais uniquement dans les cas où l'on envisage l'application de ce produit à des taux élevés dans un endroit donné pendant une période prolongée.
6. Les deux essais servant à mesurer la vitesse de réglage du pH (titrage en retour après traitement au EDTA ou à l'oxalate) étaient satisfaisants.

## OBJECTIVES

The project was divided into four objectives:

**Objective 1.** To demonstrate the treatment of organic waste materials with quicklime to interested parties and a wide range of potential users.

**Objective 2.** To establish the minimum ratio of lime when added to a range of organic waste materials to achieve temperatures necessary to produce a pasteurized product.

**Objective 3.** To (a) measure ammonia emission in each of the four organic waste materials combined with lime at levels from zero to levels in excess of those required for pasteurization and (b) measure the composition of the organic waste materials after combination with quicklime in the minimum ratio to achieve pasteurization. These measurements were: pH, total solids, volatile solids, coliform count, level of nitrogen and a range of cations.

**Objective 4.** To measure nitrogen concentration, as well as other macronutrients and micronutrients and heavy metals, in order to assess the liming and nutrient value of the resulting products containing the lime, primarily in the form of  $\text{Ca(OH)}_2$ , for application to soils. To assess the economic feasibility of this process for commercial application to the materials investigated.

## BACKGROUND

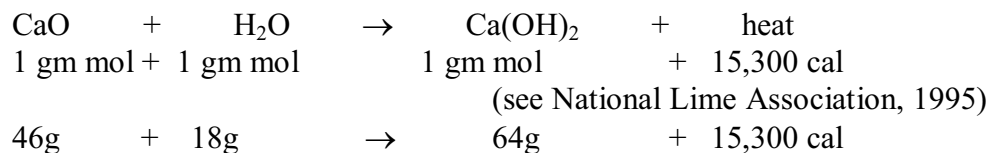
A major problem in the Fraser River basin is the management of animal wastes. The production of wastes, calculated on an animal weight basis, is as follows: dairy, 53%; beef, 16%; poultry layer, 5%; poultry meat birds, 11%; swine, 10% and horses 5% (Van Kleek, 1998). For many hog producers and poultry producers (and to a lesser extent, dairy producers), their own land bases are not sufficient for disposal within environmental guidelines (Canadian Pork Council, 1996). However, a large proportion of the waste is still spread, untreated, on the fields in the Fraser Valley. Collectively, these materials add to the load of biologically active compounds entering the Fraser River by surface runoff and the nitrates and other soluble ions entering the various aquifers. The outcome is that nitrate concentrations in some aquifers have risen to disturbingly high levels (Healey, 1997; Van Kleek, 1998). However, animal wastes are only a

component of this problem which could be greatly reduced or even overcome by the initiation of measures to balance the use of chemical fertilizers to that needed to complement the nutrients provided by animal wastes. In addition to the problem associated with the nutrient content of animal wastes, odours produced by the use of current practices have resulted in significant public pressure for modifications to be made in processing, storage and spreading methods.

Despite much success in investigations into various techniques (including aeration, solid liquid separators, composting and ultra filtration/reverse osmosis), pressure still exists to find new ways of reducing the adverse effect of the disposal of wastes in the basin. Some relief has been made with the export of poultry manure from the area to interior ranches, although this is only approximately 8% of the total amount of poultry manure produced (S. Paulson, 1998). The relatively high dry matter and nutrient concentration of poultry manure as compared to dairy or hog manure slurry makes this practice economically attractive for poultry producers, truckers and ranchers.

A major problem with regard to disposal of slurry from hog and dairy barns with slatted floors is the high concentration of water. The average moisture content of hog slurry from covered storage is 92.8% and from open storage is 98.1% (Van Kleek, 1998). High capacity expensive storage tanks are necessary for storage over the winter, at which time spreading is not permitted. Composting is an exciting alternative handling method, but for a manure handling system with no need for prior processing, this depends on a dry litter bedding system, which is not widely used in the Fraser Valley. Also, this processing method is not applicable to high-moisture slurry.

Lime pasteurization is a process that offers an alternative for the management of manure and other biological wastes. In this process quicklime (CaO) reacts with the water in the wet material with the production of heat. The heat raises the temperature, with the temperature increase being proportional to the ratio of lime to water. During the process, some of the water is driven off as vapour. There is additional moisture reduction associated with the transformation of the CaO to slaked lime [Ca(OH)<sup>2</sup>]. Calculations for this reaction are given below.



So, for a complete reaction, with 46g of quicklime added to 18g of water, the temperature of the final mass of hydroxide (64g) would be raised by 239 centigrade degrees (15300/64), if the specific heat (calories to raise the temperature of 1g of the substance 1°C) of the hydroxide were 1. However, specific heat varies from substance to substance and is affected by temperature (Lange, 1934). Also, in waste materials the water is associated with varying proportions of dry matter (organic and inorganic), which would absorb heat and thus reduce the rise in temperature. Consequently a precise prediction of the temperature rise in a mass of wet material during and after treatment is not possible.



Because of the heating associated with the reaction, water vapour is lost. This modifies the residual weight of the treated material after the temperature has returned to ambient levels. The present project will provide information on this aspect.

The lime pasteurization process can be applied to the conversion of a variety of high-moisture wastes (e.g. fish morts and offal, water-reduced hog manure and sewage sludge) to a stable low-moisture (15-17%) pathogen-free low odour nutrient-enhanced hydrated lime-containing product (see Appendix 1). With manure handling being a costly component of farm operation, the use of lime treatment for unprocessed hog slurry would seem to be unnecessary and expensive (Van Kleek, 1998). However, the residue remaining after removal of much of the water by reverse osmosis/ultrafiltration or by lime treatment followed by polymer flocculation (B.C. Pork Producers Association, 1997) would be suitable for lime treatment, if economics warranted such treatment.

The equipment for treatment of waste with lime is simple and inexpensive, and could be made of varying capacity, such as to be suitable for locating at the source of the waste material. Alternatively, higher capacity mobile equipment, similar to that currently being used by the Chemical Lime Group for demonstration (see Figures 1-8) could be a viable alternative. The end-product could be stored indefinitely, with the quantity limited only by the capacity of the storage vessels or the space for free-standing piles (see Figure 5). The end-product is of value as a soil amending agent for acid soils, which occur widely in the Lower Fraser Valley and Vancouver Island. This process thus serves two purposes, *viz.* to manage a waste product effectively and to defray costs by delivering lime to areas with acidic soils, where liming has generally been shown to enhance crop and pasture production.

Lime pasteurization produces a reduced moisture content pasteurized sterile soil conditioner from the combination of lime and liquid waste. This partially dried conditioner could be used in place of the liquid waste material and at a time of the year when it is more suitable for crop production, thereby reducing the movement of deleterious materials into the Fraser River. Thus, the needs of the agriculture industry and the Fraser River could be met. This product could be customized to produce a balanced fertilizer by the addition of other nutrients. Indeed, such a process has been patented in Belgium (Chemical Lime Co., 1998). It should be noted that the commercial use of lime in the lower mainland of 20,000 tonnes is already a standard practice for soil pH adjustment. Therefore the use of lime-treated biosolids would allow a combination of two traditional practices into one which is more environmentally sound.

## METHODS AND RESULTS

### **Objective 1. Demonstration of process.**

The organic waste materials that were selected for demonstration were (a) municipal sludge (biosolids) from an anaerobic digestion process (District of Chilliwack), (b)

municipal sludge (biosolids) from an aerobic digestion process (District of Kent), (c) fish offal, (d) liquid dairy cattle manure and (e) poultry layer manure.

The demonstration of lime treatment of anaerobic digested sludge at the District of Chilliwack waste water treatment plant (WWTP) took place on 13th November, 1996. Attendance is listed in Table 1.

**Table 1. Attendance at District of Chilliwack Demonstration**

<b>Organization</b>	<b>Name</b>	<b>Telephone No.</b>
Environment Canada	Ms. Lisa Walls	604-666-6262
ditto	Ms. Vivian Au	ditto
Agriculture and Agri-Food Canada	Dr. John Paul	604-666-2221
ditto	Dr. Tissa Kannangara	ditto
ditto	Mr. Shaobing Yu	ditto
ditto	Mr. Mussolini Kithome	ditto
ditto	Mr. Philip Barton	ditto
BC Ministry of Agriculture Fisheries and Food	Mr. Orlando Schmidt	604-556-3095
City of Chilliwack (engineer)	Mr. Philip Blaker	604-792-9311
City of Vancouver Health Board	Mr. Peter Jacobs	604-736-2866
ditto	Mr. Rik Bernard	ditto
Lummi Sewer District, WA.	Mr. Rob Jefferson	360-758-7167
ditto	Mr. Victor Solomon	ditto
City of Sedro-Wooley, WA.	Mr. Dale Velasquez	360-856-1100
City of Everson, WA.	Mr. Rick Holt	360-966-4142
PGL Organics Ltd.	Mr. Chris Bullock	604-895-7616
Techni-Gro Canada	Mr. Brian Pauwels	604-792-0097
Nova Tec WTI	Ms. Catherine Ponsford	604-873-9262
West Coast Reduction (Env. coord)	Mr. Ken Ingram	604-255-9301
Earth Tech, Bellevue, WA.	Mr. George Nordby	206-455-9494
ditto	Mr. Chen Shen	ditto

The demonstration of lime treatment of aerobic sludge at the District of Kent WWTP took place on 14th November, 1996. Attendance is given in Table 2.

**Table 2. Attendance at District of Kent demonstration**

<b>Organization</b>	<b>Name</b>	<b>Telephone No.</b>
District of Kent (Engineer)	Mr. Keith Paisley	604-796-2235
District of Kent (WWTP)	Mr. Willis Dyer	604-796-9145
ditto	Mr. Ian Gardner	ditto

The demonstration of lime treatment of PARC dairy cattle manure (barn floor scrapings), PARC layer manure and commercial fish offal took place on 28th November, 1996. Attendance is given in Table 3.

**Table 3. Attendance at PARC demonstration**

<b>Organization</b>	<b>Name</b>	<b>Telephone No.</b>
Agriculture and Agri-Food Canada	Dr. Grant Kowalenko	604-666-2221
Darcy Springs Hatchery	Mr. Don MacQuarrie	604-657-2843
Seafoods Products Co. Ltd.	Mr. Ken (Sak) Kariatsumari	604-255-3141
Fishery consultant	Mr. Bob Wiggen	604-946-6201
Alfa Laval Eng. Co.	Mr. Chris Pook	604-857-0286
Biozyme Systems Inc.	Mr. David Saxby	604-324-0002
ditto	Mr. Ron Clark	604-856-2017

Each of the above demonstrations was attended by CLC management (Mr. Scott Hinds, General Manager, Mr. Bob Boseman, Plant Manager) and the equipment operator and the truck operator. Dr. Starr Curtis (CLC) set up and operated the equipment for the Chilliwack and Kent demonstrations. Mr. Jim Piers (CLC, sales representative) attended the Chilliwack and PARC demonstrations and Mr. Andrew Grzymek (CLC, process engineer) attended the Chilliwack demonstration. Personnel from PARC listed in Table 1 and Mr. Ian Shand and Dr. Dick Beames attended all demonstrations.

### **Demonstration operating conditions**

At each of the sites (Chilliwack, Kent, PARC), varying lengths of time were required to achieve the desired ratio of lime to waste material, which was set at achieving a temperature of 70-80° C approximately 5 minutes after processing, at which time the temperature seemed to stabilize. Throughout the processing some of the material was below this temperature and, where the lime concentration was too high, the temperature sometimes rose to over 100° C. On the whole, these fluctuations resulted from feed

problems, which had been overcome by the time of the PARC demonstration. It must be emphasized that this mobile treatment plant had been designed to demonstrate the process on large amounts of waste organic material (in excess of 20 tonnes). In such processing, the initial fluctuations in the ratio of lime to waste material as the machine was being "settled in" would occur in only a small proportion of the total material processed.

When the proportions of lime to waste material was such that temperature was raised to 70-80° C a crumbly texture was produced and the treated material attained an angle of repose of approx. 45° for all materials treated, even though piles of approximately 10

tonnes of some of these materials prior to treatment attained a height of no more than 40cm. (e.g. fish offal).

During the processing, large quantities of water vapour were produced, and, from the smell (and based on CLC experience), contained dissolved ammonia. This had been identified as a potential problem with this processing procedure, mainly from the aspect of environmental pollution. However, CLC has developed a simple scrubbing process which is currently in use in Alabama and elsewhere in the USA. This consists of a water scrubber (ammonia is highly soluble in water), followed by a dilute acid scrubber. In appropriate situations, this captured ammonia can be processed into fertilizer or put back into the system.

Mr. Keith Paisley, Municipal Engineer, District of Kent, is currently investigating the potential acceptance of the processed aerobic sludge as a class A (American standards, see appendix 1) soil amendment material. He considers that this will provide an option for disposing of the sludge locally as a lime amendment material for acid soils.

### **Objective 2. Establishing minimum level of lime needed for pasteurization.**

The four organic wastes tested were: anaerobic digested sludge (biosolids) from the District of Chilliwack, fish offal, semi-solid dairy cattle manure and poultry layer manure. The District of Chilliwack biosolids (from an anaerobic process) were chosen for testing over the District of Kent biosolids (from an aerobic process) because of the much wider use of the anaerobic process in waste water treatment plants, and thus a much wider applicability of the results.

### **Methods**

The design was a 4x4 factorial, with two replicates per treatment. There were 4 organic wastes (see above), each treated with 4 levels of quicklime (zero and levels 1,2 and 3), with the upper levels being arranged to exceed the "optimal" level (raising the core temperature to over 70°C) by a small margin. An extra level was tested with the fish offal. The maximum level of lime added differed between materials, being 25% for the sludge biosolids, 40% for the dairy and poultry wastes and 60% for the fish offal. Lime and organic material was mixed in a mortar mixer, with the mixture immediately transferred to steel drums. Core temperature was measured immediately after and approximately 3 hours after treatment. The results were analyzed by analysis of variance and the means compared by a multiple range test.

## Results and discussion

The results are summarized in Table 4.

**Table 4. Relationship between quicklime concentration and temperature when lime is added to various waste materials**

Lime/waste (%)	Temperature (°C)							
	C'wack biosolids		Fish offal		Dairy manure		Poultry manure	
	Initial*	3 hrs**	Initial	3 hrs	Initial	3 hrs	Initial	3 hrs
0	9.5	9.5	2.5	2.5	8.5	13	9.5	11
15	55	63.5						
20	69	<b>72.5</b>	20	51	35	58.5	43.5	74
25	60	76.5						
30			45.5	<b>88</b>	<b>87</b>	<b>75</b>	<b>85</b>	<b>86</b>
40			98	99.5	97.5	78	90.5	85
60			99	84				

\*immediately after the addition of lime.

\*\*Hours after addition of lime.

Numbers in bold (temperatures over 70°C) determined minimum ratio for pasteurization.

The results in Table 4 indicate that 20% lime is adequate for treatment of the Chilliwack biosolids; that 30% is more than adequate for fish offal and dairy manure, and that with testing between 20% and 30% a slightly lower percentage could have been found to be satisfactory for each of these products, and that 20% was adequate for poultry waste.

With several factors (particularly moisture content and specific heat values of the solids) dictating the temperature response to the addition of lime, exact ratios of addition needed for any particular material would have to be determined by trial and error. It is expected that initial additions would be on the high side in order to ensure pasteurization and then the concentration reduced to a level just adequate for pasteurization. The only disadvantage of overliming would be the unnecessary expense.

### **Objective 3. To measure ammonia emissions and composition of lime-treated products**

#### **Methods**

Detailed measurements of ammonia emission were made on a bench scale on each of the materials, with lime concentrations ranging from zero to levels higher than those required for pasteurization. In these laboratory tests, ammonia emissions were measured for various intervals up to 168 hours. These samples were also analyzed for dry matter, ash, total N, ammonia N, pH, and coliforms .

Measurements of ammonia emissions in the laboratory on the various wastes were achieved by reacting the lime and the waste in a closed vessel and trapping the ammonia produced in sulphuric acid. The nitrogen content in the acid trap was analyzed by the standard methods (AOAC, 1990) using the Kjeldahl principle. After addition of the lime to the raw materials, the reaction flasks containing raw material and lime were kept in a water bath maintained at 55°C to mimic the exothermic reaction created by the mixing of the waste with the lime. Ammonia emissions were measured in three separate experiments. Experiment 1 consisted of two replicates of each of the two municipal sludge biosolids. Lime rates included 0,5,10, 20, 30 and 40% of the weight of the fresh waste. Experiment 2 consisted of four replicates of the fish offal because of the heterogeneity of the waste material. Lime rates included 0,20, 25,30,35 and 40% of the waste. Experiment 3 consisted of two replicates of dairy cattle slurry and poultry layer manure, with lime added at rates of 0,5,10,20,30 and 40%.

## Results

### *Ammonia emission*

Data from laboratory tests for emissions up to 168 hours are given for biosolids from the District of Chilliwack and the District of Kent in Table 5, for fish offal in Table 6 and for dairy cattle slurry and poultry layer manure in Table 7. Data for dry matter, ash, total nitrogen, ammonia nitrogen, pH and coliforms are given in Table 8.

#### *(a) District of Chilliwack and District of Kent biosolids*

Ammonia emission increased dramatically in response to addition of quicklime to both the District of Chilliwack biosolids and the District of Kent biosolids (Table 5). Most of the emission occurred during the first 24h period during which time the chemical reactions were taking place. This, in combination with the increased temperature, would be expected to fairly closely parallel the conditions in a larger pile. Ammonia emission measurements beyond this period was somewhat artificial because the exposure of the small sample weight used in these tests (30g) to the air were not typical of what would happen in a large waste storage pile. It would be expected that the delayed losses in large storage piles would be considerably attenuated because of a reduction in surface to weight ratio as volume increases.

Ammonia emissions in the first 24 hours increased with lime rate up to 10%. At a lime addition rate of 20%, which was the rate required for pasteurization, ammonia emission was more than 6 times higher than with the control (0% addition) for both the District of Chilliwack biosolids and the District of Kent biosolids (Table 5).

Ammonia emissions were significantly higher from the District of Chilliwack biosolids than for the District of Kent biosolids. This reflects the type of process used at the



wastewater treatment plants. The District of Chilliwack utilizes anaerobic digestion, whereas the District of Kent uses aerobic digestion. Aerobic digestion can be expected to result in significantly lower ammonium concentrations in the biosolids than an anaerobic process, but to have greater emissions during sludge treatment.

**Table 5. Ammonia emissions from biosolids from the District of Chilliwack and the District of Kent amended with various rates of quicklime and incubated at 55°C.**

Lime (%)	Ammonia emission (mg ammonia N/g fresh sample)							
	Chilliwack Biosolids				Kent Biosolids-			
	0-24h	24- 48h	48- 168h	Total	0-24h	24- 48h	48- 168h	Total
	0	0.17	0.26	0.11	0.54	0.12	0.49	0.05
5	0.77	0.21	0.04	1.03	0.33	0.22	0.03	0.58
10	1.10	0.20	0.04	1.34	0.61	0.21	0.03	0.84
<b>20*</b>	<b>1.08</b>	<b>0.18</b>	<b>0.04</b>	<b>1.29</b>	<b>0.72</b>	<b>0.23</b>	<b>0.03</b>	<b>0.98</b>
30	1.17	0.18	0.02	1.37	0.67	0.17	0.04	0.87
40	1.13	0.22	0.03	1.38	0.63	0.17	0.03	0.83
SEM**	0.22	0.03	0.01	0.23	0.04	0.05	0.01	0.08

\*Numbers in bold represent lime rate that met temperature requirements for pasteurization

\*\*Standard error of mean, 6 levels, 2 replications

(b) *Fish offal*

With fish offal there was no significant difference in ammonia emission between the rates of lime addition of 20% and 40% (Table 6). The lime treated wastes produced 21% to 61% more ammonia than the control (non-treated) waste for the first 24 hours. However, for the remaining period (24 to 168 hours), ammonia emission virtually ceased for all of the lime treatments, whereas the untreated waste continued to produce ammonia at a high level. Total ammonia emission for the total 168 hour period was 1.5 times higher for the untreated material than for any of the lime treatments. This demonstrates the stabilizing value of the lime treatment of fish offal. These results can be explained by the inactivation of microbial action as a result of pasteurization and the high residual pH. Even the high pH of 11.7 (see Table 8) without prior pasteurization would have been adequate for the prevention of microbial growth (Beames, 1960). This difference in response with the fish waste can be attributed to the fact that the nitrogen was mostly in the form of intact protein and was amenable to microbial degradation, whereas the nitrogen in the other materials had already been modified to inorganic forms.

**Table 6. Ammonia emission from fish offal amended with various rates of quicklime and incubated at 55°C.**

Lime (%)	Ammonia emission			
	(mg ammonia N/g fresh fish offal)			
	0-24h	24-48h	48-168h	Total
0	0.83	0.65	0.39	1.87
20	1.01	0.01	0	1.02
25	0.99	0	0	0.99
<b>30*</b>	<b>1.34</b>	<b>0.03</b>	<b>0</b>	<b>1.36</b>
35	1.36	0.01	0.1	1.47
40	1.12	0.04	0	1.16
SEM**	0.15	0.11	0.08	0.28

\*Numbers in bold represent lime rate that met temperature requirements for pasteurization

\*\*Standard error of mean, 6 levels, 4 replications

The results for fresh fish offal indicate that the addition of lime drives off virtually all of the ammonia during the first 24 hours, producing a stable storable product, with almost no further emission of ammonia. Such a result shows this treatment to have considerable potential for the handling and storage of fish offal. This stabilization would allow great flexibility in a fish processing operation, where the product could be disposed of as a soil amendment material at a time convenient to the producer. Treatment of the offal when fresh is considered to be highly desirable, if not essential.

*(c) Dairy cattle slurry and poultry layer manure*

For all of the treatments on dairy cattle manure (zero and 5% to 40%), over 90% of the total ammonia emission occurred over the first 24 hours (Table 7). The addition of lime to dairy cattle slurry significantly increased ammonia emission by 7 to 21%, with these increases occurring during the first 24 hours.

Ammonia emissions were almost four times higher from the poultry layer manure than from the dairy cattle slurry and the fish waste, and approximately 5 to 7 times higher than the emissions from the two municipal biosolids. The response of the poultry layer manure to addition of quicklime was unique (Table 7), in that the lime addition not only increased the ammonia emission over the first 24 hour period (approx. threefold) but markedly reduced emissions in the 10% to 40 % treatments for the remainder of the experimental period.

The results in Table 7 show that ammonia emission of the lime-treated organic materials is significantly increased by lime addition. The ammonia emission is greatly increased during the first 24 hours, which aids in the management of such material by the use of ammonia scrubbers. With this greater early removal of ammonia, it is expected that there

would be a reduction in ammonia loss after application of the treated wastes to the field, with the loss being markedly less than that which would occur if untreated manure were to be spread.

**Table 7. Ammonia emission from fresh dairy cattle slurry and fresh poultry layer manure amended with various rates of quicklime and incubated at 55°C.**

Lime (%)	Ammonia emission							
	(mg ammonia N/g fresh sample)							
	Dairy cattle slurry				Poultry layer manure			
	0-24h	24-48h	48-168h	Total	0-24h	24-48h	48-168h	Total
0	1.21	0.06	0.06	1.32	1.57	0.83	1.56	3.96
5	1.33	0.04	0.05	1.42	4.99	0.67	0.13	5.8
10	1.35	0.04	0.06	1.45	5.34	0.19	0.07	5.6
20	1.48	0.03	0.06	1.57	5.33	0.16	0.09	5.58
<b>30*</b>	<b>1.49</b>	<b>0.06</b>	<b>0.06</b>	<b>1.61</b>	<b>5.48</b>	<b>0.02</b>	<b>0.08</b>	<b>5.76</b>
40	1.5	0.04	0.06	1.6	5.35	0.16	0.08	5.58
SEM**	0.06	0.01	0.00	0.06	0.41	0.16	0.12	0.38

\*Numbers in bold represent lime rate that met temperature requirements for pasteurization

\*\*Standard error of mean, 6 levels, 2 replications

Addition of lime only had a small effect on dairy cattle slurry both with regard to initial ammonia loss and loss over 168 hours, so would not appear to have much application as a means of reducing field ammonia losses. In contrast, lime addition to poultry layer manure markedly increased initial ammonia loss over the first 24 hours and virtually eliminated loss thereafter, thus suggesting that this process would be suitable for stabilizing this manure if an ammonia scrubber were to be used.

*Physical and chemical parameters and coliform content of lime-treated materials*

For all waste materials, the addition of lime increased the pH from a range of 7 to 8 to a final value of 11.7 to 11.8 (Table 8). This was accompanied by an increase in dry matter percentage to levels ranging from 47.8% to 60.5%. The increase was greatest for the dairy cattle slurry (from 14.8% to 53.3%). Calculations were made to determine the loss of moisture as vapour resulting from the heating of the treated material (appendix 2). With the poultry manure used as an example, this showed that from an initial weight of 100g manure of approximately 74% moisture, when treated with 30g lime, the final weight was 113g, with approximately 40% moisture. In all cases the lime treatment reduced coliform count to undetectable levels. With an increase in the ash percentage in the dry matter, largely as a result of the addition of the lime (100% ash or inorganic

matter), there was a concomitant reduction in the organic matter percentage of all materials. Total nitrogen level was also reduced, also largely through the diluting effect of the addition of the lime, but with the contribution from the loss of nitrogen as ammonia. For all lime-treated materials, the level of nitrogen as ammonium nitrogen was 2% or less (more detailed information can be obtained from Dr. C G. Kowalenko, PARC).

The significance of the other elements (aluminum, arsenic, cadmium, copper, iron, lead, magnesium, mercury, potassium, phosphorus, sodium and zinc) is discussed under objective 4 (below).

The lime-treated materials used for the temperature and ammonia experiments were placed into covered barrels and stored until the laboratory assessments were initiated. All materials, particularly the fish offal, produced a fair amount of odour when the barrels were opened, even though the decomposition was visually quite complete. The odour from the fish offal was quite distinct and persisted for quite a while after the samples were dried, screened and stored. The odour seemed to diminish slowly over time. This suggests that there is a continuing slow chemical reaction, including a possible oxidation of oils, after the initial vigorous reaction. The storage in the closed drum would have added to this odour. This also suggests that some of the chemical assessment measurements may change with time as the chemical reaction proceeds.

**Objective 4. To measure nitrogen concentration, as well as other macronutrients and micronutrients and heavy metals, in order to assess the liming and nutrient value of the resulting products containing the lime, primarily in the form of  $\text{Ca}(\text{OH})_2$ , for application to soils.**

The original intent for comparing the lime-treated materials was to incorporate glass house tests with the use of various acid-sensitive plants. Because of the labour and time requirements of such tests, they were replaced by laboratory tests. These laboratory tests were carried out on four acidic soils, with comparisons made with conventional liming materials and laboratory grade calcium carbonate for extent and speed of reaction. Comparative tests were also made on methods for assessing speed of reaction. Details on the results with the different methods can be obtained from Dr. C.G. Kowalenko, PARC.

### **Methods**

For the laboratory tests, all of the lime-treated materials taken from the drums used for the temperature and ammonia tests were air-dried to reduce the moisture content from approximately 66-85% to 18-24%. A fine (<3mm) fraction and a coarse (3-6mm) fraction were prepared by forcing through screens.

**Table 8. Values from laboratory tests for pH, dry matter, ash, organic matter, total nitrogen, ammonium nitrogen, minerals and coliforms in fresh (untreated) and lime-treated waste materials**

	Chilliwack biosolids		Fish offal		Dairy cattle slurry		Poultry layer manure	
	Raw	Treated	Raw	Treated	Raw	Treated	Raw	Treated
<b>Lime addition</b>		<b>20%</b>		<b>30%</b>		<b>30%</b>		<b>30%</b>
<b>As-is basis</b>								
pH	7.0	11.8	6.9	11.7	7.7	11.7	8.0	11.8
Dry matter (%)	33.3	47.8	25.5	54.7	14.8	53.3	26.9	60.5
Moisture (%)	66.7	52.2	74.5	45.3	85.2	46.7	73.1	39.5
Coliforms (CFU/g)	>240000	<3	2530	<3	35000	<3	>240000	<3
<b>Dry matter basis</b>								
Ash* (%)	46.2	79.8	41.6	85.9	16.8	93.5	39.8	84.0
Organic matter (%)	53.8	20.2	58.4	14.1	83.2	6.5	60.2	16.0
Total N (%)	3.7	1.8	9.1	3.0	2.0	0.5	3.1	1.6
NH <sup>4</sup> -N (%)	0.28	0.02	0.43	0.07	0.02	0.002	0.53	0.05
Calcium (%)	3.51	24.50	1.88	19.55	0.17	21.20	2.51	19.75
Aluminum (mg/kg)	19050	9610	6	124	90	204	126	206
Arsenic (mg/kg)	6.7	4.9	2.8	3.2	1	1.6	1	1.2
Cadmium (mg/kg)	3.9	2.0	0.18	0.10	0.10	0.08	0.09	0.1
Copper (mg/kg)	1205	616	2.0	2.1	4.2	5.8	22.2	19.0
Iron (mg/kg)	17150	8545	35	186	139	302	357	393
Lead (mg/kg)	107	55	0.4	1.1	0.5	1.1	1.4	1.5
Magnesium (mg/kg)	4245	3475	264	2230	736	2235	1750	2775
Mercury (mg/kg)	4.9	1.9	-	-	-	-	-	-
Molybdenum (mg/kg)	9.4	5.5	0.1	0.2	0.3	0.5	1.2	1.2
Nickel (mg/kg)	29.3	13.4	0.1	<0.1	0.4	0.3	3.6	1.2
Potassium (mg/kg)	1445	1190	2380	2360	6265	6065	5750	4990
Phosphorus (mg/kg)	2652	302?	2270	1760	852	934	7950	6280
Sodium (mg/kg)	643	444	1965	1950	356	631	1455	1535
Zinc (mg/kg)	936	479	17.2	14.8	15.1	18.3	153.5	114.5

\*Residue after incineration at 550°C.; 100-%volatile solids.

In addition to tests and parameters measured in Table 8, further tests were made on the lime-treated materials. These included calcium carbonate equivalents (a measure of liming value) using the method of Kane (1995), and liming intensity (a measure of the rate of the change of pH with the liming of a soil). For the latter, a variety of methods were compared, including the EDTA method (see ElGibaly and Axley, 1955; Whittaker et al. 1963 and Hunter et al. 1963) and the oxalate method (Thomas and Gross 1952 and Schollenberger and Whittaker 1956). This second method was used for the information presented in Tables 12 and 13. The results from the comparison of methods will not be discussed here, but details can be obtained from Dr. Kowalenko (PARC). Calculations were made on the limiting effect of the concentrations of non-neutralizing chemicals on the potential value of these lime-treated materials for soil application (Table 15). Levels of carbon (C) and sulphur (S) were measured, and C/nitrogen(N), and C/S values were calculated (Table 10).

**Table 9. Calcium carbonate equivalents of lime-treated waste materials and commercial lime products\***

Lime sources	Lime: fresh waste	Calcium		CaCO <sub>3</sub> equivalent‡		
		(% air-dry)	(% dry matter)	AOAC** method	Relative to Ag lime	
				Dry matter basis		Non- dried†
Biosolids	20:100	11.7	24.5	18.6#	36	17
Fish offal	30:100	10.7	19.5	28.7#	55	30
Dairy slurry	30:100	11.3	21.2	32.7#	63	34
Poultry manure	30:100	11.9	19.7	19.8#	38	23
Quicklime		72	72	90.3	172	172
Hydrated lime		50	50	76.3	146	146
Ag. Lime		38	38	52.2	100	100
Dolomite		34 (+23Mg)	34(+23Mg)	56.2	107	107

‡ Standard error of mean (SEM) of CaCO<sub>3</sub> equivalent of 20 measurements (4 waste materials, 2 fineness of grind, 2 runs) plus 4 commercial materials, with 3 reps per run is 2.44

\*Information from data provided by Dr. Kowalenko. Levels of calcium in commercial liming products were obtained from National Lime Association 1995.

\*\*Kane, 1995.

#Oven-dry material, mean value of coarse and fine grind

† See Table 8 for moisture contents of lime-treated materials

Four soils were used for testing the lime-treated materials. These were Mud Bay, which is very acidic, Abbotsford, which is moderately acidic and two farm soils of intermediate acidity (Table 10). Results for liming potential (calcium carbonate equivalent) are presented only for the extremes, viz. Mud Bay and Abbotsford soils.

## Results

Information on the soils used is presented in Table 10.

The liming value (calcium carbonate equivalent) of the various lime-treated materials is presented in Table 11. The potential limiting effect of the various macro-elements and nutrients on the maximum addition of the lime-treated materials is presented in Table 14.

The information in Table 11 indicates that, when the lime-treated organic materials are compared with agricultural limestone, application rates would have to be about 5 times



higher for sludge biosolids, four time higher for poultry manure and approximately three times higher for fish offal and dairy manure. On a dry matter basis, these replacement levels would be reduced by approximately 50%.

**Table 10. Characterization measurements on soils used for assessment of quicklime-treated organic materials as liming agents**

Measurement	Mud Bay	Abbotsford	Farm #21	Farm #2c
pH by: - 1:1 soil:water	4.00	5.87	4.61	4.61
- SMP buffer	4.89	6.52	6.42	5.64
Tonnes CaCO <sub>3</sub> equivalent/ha to 20 cm depth to achieve pH 6.5*	20.04	3.63	4.43	11.74
Carbon (%)	7.54	4.73	1.44	6.81
Nitrogen (%)	0.4168	0.3492	0.1593	0.6364
Sulphur (%)	0.5002	0.0585	0.0198	0.1112
C:N ratio	18	14	9	11
C:S ratio	15	81	73	61

\*Lime requirement calculated by:  $L.R. (6.5) = 1.189 (SMP)^2 - 23.60 (SMP) + 107.07$

**Table 11. Amount of quick-lime-treated organic materials and commercial liming products that would have been added (mT/ha to 20 cm depth) at calcium carbonate equivalents recommended to lime soils to pH 6.5 using SMP buffer method**

Material	Moisture (%)	Maximum (Mud Bay soil)	Minimum (Abbotsford soil)
Biosolid	52.2*	103	20
Fish offal	45.3	54	12
Dairy slurry	46.7	46	11
Poultry manure	39.5	83	16
Quicklime	<1	12	2
Hydrated lime	<1	15	3
Agricultural limestone	4.1	23	4
Dolomite	<1	20	4
Pure calcium carbonate	<1	20	4

\*Moisture content of material in drums after treatment.

Data provided by Dr. Kowalenko were modified to moisture levels in the drums.

Data for liming intensity are presented in Tables 12 and 13. The values for one-hour changes in pH show all of the lime-treated materials to be fast acting and not markedly different from the liming intensity of quicklime. Slaked lime was significantly faster, while agricultural limestone and dolomite were markedly slower (Table 12). However,

these differences had largely disappeared by 22 hours (Table 13). Extrapolation of these results to pH changes in soils would appear to be better made from the 1-hour data than from the 22-hour data, because when conventional liming materials are added to soils, differences in the change in pH is considerably more rapid with quicklime and slaked lime than with either agricultural limestone and dolomite, particularly dolomite. With these results showing no marked effect of fineness of particle size of lime-treated materials (<3mm and 3-6mm) it is likely that the fine particle size of the original quicklime is not greatly modified during the liming process.

**Table 12. Oxalate measurements at 1 hour of liming-intensity potential of quicklime-treated organic materials and commercial liming products**

Organic materials /Liming products	Size	Run 1	Run 2	Material x Size mean	Material/Size mean
C'wack Biosolid	Coarse	4.41efg	4.42efg	4.42	----
	Fine	3.93gh	4.84bcde	4.38	4.40
Fish offal	Coarse	4.72cde	5.18bc	4.95	----
	Fine	5.21bc	5.33b	5.27	5.11
Dairy slurry	Coarse	5.12bcd	4.61def	4.86	----
	Fine	5.21bc	5.12bcd	5.16	5.01
Poultry manure	Coarse	3.76h	4.08fgh	3.92	----
	Fine	4.02gh	4.05gh	4.03	3.97
Mean of organics	Coarse	----	----	----	4.54
	Fine	----	----	----	4.72
Quick lime	N.A.	----	----	----	4.47efg
Hydrated lime	N.A.	----	----	----	7.64a
Agric. limestone	N.A.	----	----	----	0.88i
Dolomite	N.A.	----	----	----	0.61i

Standard error of mean (SEM) of 20 values (with superscripts) is 0.19

Data in Table 14 indicate that the macro-nutrients contained in the various lime-treated organic materials would not have a serious limiting effect on the use of these materials as a sole source of lime for the Abbotsford soil, although the level of nitrogen in fish offal was high, as were levels of sulphur, phosphorus and magnesium in the sludge biosolids and levels of nitrogen, phosphorus and magnesium in poultry waste.

In contrast to the above, the high requirement of lime for the Mud Bay soil would mean that the use of lime-treated materials as a sole amending agent would provide a gross excess of the major nutrients, except perhaps, for the dairy waste.

Information on the levels of the micro-elements presented in Table 15 shows that several of these elements, if the sludge biosolids were to be used as the sole liming material on the Mud Bay soil, would soon exceed the maximum acceptable levels set by the Food Production and Inspection Branch (Agriculture and Agri-Food Canada, 1996) for a 45 year period. In contrast, trace element contamination would not appear to be a serious problem with the Abbotsford soil, either for the other lime-treated materials (fish offal, poultry manure and dairy slurry), but caution would still be required for the lime-treated biosolids if used as the sole liming agent, where accumulations of concern could still occur in a relatively few years (zinc, molybdenum, selenium and mercury, 40 to 80 years).

**Table 13. Soil pH after equilibration for 22 hours of liming-intensity potential of quicklime-treated organic materials and commercial liming products**

Organic materials /Liming products	Size	Run 1	Run 2	Material x Size mean
Biosolid	Coarse	6.81abc	6.67bcd	6.74
	Fine	6.77abcd	6.72bcd	6.74
Fish offal	Coarse	6.84ab	6.70bcd	6.77
	Fine	6.70bcd	6.69bcd	6.70
Dairy slurry	Coarse	6.61d	6.92a	6.76
	Fine	6.75abcd	6.74abcd	6.74
Poultry manure	Coarse	6.66bcd	6.63cd	6.64
	Fine	6.63cd	6.77abcd	6.70
Quick lime	----	----	----	6.04e
Hydrated lime	N.A.	----	----	6.19e
Agric. limestone	N.A.	----	----	5.58f
Dolomite	N.A.	----	----	5.17g

Standard error of mean of 20 values (with superscripts) is 0.06

Because of the substantial levels of macroelements provided by the lime-treated materials if applied at liming rates, they would be categorized, most likely, as “novel or new pH altering products” under the Fertilizer Act ((Food Production and Inspection Branch 1996) and thus would likely need efficacy and safety to be demonstrated before they could be registered for marketing in Canada.

**Table 14. Amount of macro- and secondary-nutrients added when quicklime-treated organic materials would be added at calcium carbonate equivalents recommended to lime soils to pH 6.5 using SMP buffer method in comparison to a high fertilizer application rate**

Element	Source of material	Maximum (Mud Bay soil)	Minimum (Abbotsford soil)	A maximum fertilizer recommendation
		-----Tonnes/ha to 20 cm depth-----		
Carbon	Biosolid	25.6	2.4	---
	Fish	10.9	1.7	---
	Dairy	6.4	1.0	---
	Poultry	16.2	2.5	---
Calcium	Biosolid	23.7	3.0	---
	Fish	12.0	1.4	---
	Dairy	9.8	1.5	---
	Poultry	17.6	2.4	---
		-----kg/ha to 20 cm depth-----		
Nitrogen	Biosolid	1978 (20)*	187 ( 2)	180
	Fish	1694 (34)	231 ( 5)	180
	Dairy	224 ( 1)	33 (<1)	180
	Poultry	1419 (57)	213 ( 9)	180
Sulphur	Biosolid	367	33	15
	Fish	73	9	15
	Dairy	11	2	15
	Poultry	81	11	15
Phosphorus	Biosolid	10498	103	40
	Fish	117	11	40
	Dairy	48	7	40
	Poultry	539	77	40
Potassium	Biosolid	112	84	95
	Fish	123	20	95
	Dairy	282	42	95
	Poultry	403	66	95
Magnesium	Biosolid	321	44	20
	Fish	143	15	20
	Dairy	110	15	20
	Poultry	227	37	20

\*Amount in brackets = ammonium (kg N/ha to 20cm depth) added by the material

**Table 15. Amount (kg/ha/yr to 20 cm depth) of various micronutrients, contaminant metals and other elements added when quicklime-treated organic materials would be added at calcium carbonate equivalents recommended to lime soils to pH 6.5 using SMP buffer method in comparison to a high fertilizer application rate**

Element	Material	Maximum (Mud Bay soil) (kg/ha/yr)	Minimum (Abbotsford soil) (kg/ha/yr)	Maximum 45 year addition*	Years of organic additions to reach 45 year maximum for Mud Bay soil**
Iron	Biosolid	939	92	---	---
	Other 3	33	2	---	---
Manganese	Biosolid	26	3	---	---
	Other 3	10	<1	---	---
Copper	Biosolid	68	7	---	---
	Other 3	2	<1	---	---
Zinc	Biosolid	49	5	370	8
	Other 3	9	<1	370	41
Molybdenum	Biosolid	0.65	0.06	4	6
	Other 3	0.10	<0.01	4	40
Selenium	Biosolid	0.61	0.06	2.8	5
	Other 3	0.13	<0.01	2.8	22
Aluminum	Biosolid	1060	93	---	---
	Other 3	17	2	---	---
Mercury	Biosolid	0.23	0.02	1	4 (1/0.02=50)
	Other 3	N.D.	N.D.	1	N.A.
Lead	Biosolid	6.11	0.06	100	16
	Other 3	0.12	0.01	100	833
Cadmium	Biosolid	0.23	0.02	4	17
	Other 3	0.01	<0.01	4	400
Nickel	Biosolid	1.32	0.22	36	27
	Other 3	<0.01	<0.01	36	>3600
Arsenic	Biosolid	0.44	<0.01	15	34
	Other 3	<0.01	<0.01	15	>1500
Cobalt	Biosolid	0.22	<0.01	30	136
	Other 3	<0.01	<0.01	30	>3000

\* Maximum accumulation acceptable in soil over 45 years (kg/ha to undocumented depth) according to Food Production and Inspection Branch "Standard for Metals in Fertilizers and Supplements"

\*\* Column 5 divided by column 3

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## APPENDICES

### Appendix 1. Stabilization and pasteurization categories

Information supplied by Chemical Lime Company on stabilization and pasteurization is given below (US categories for pathogen loads):

**Stabilization.** Achieves Class B pathogen reduction with all types of sludge. Achieves both pathogen reduction and vector attraction reduction criteria. Works with low solids liquid sludge as well as dewatered sludge. Add-on process to digestion to ensure certification as Class B. Process can be upgraded to Class A pathogen reduction. Good long-term odour control (3 months). Easy process to monitor and control. Disposal options include: land application, surface disposal and landfilling. Low capital costs. Turnkey processing and handling systems available. Rapid implementation for interim or permanent solution. On-site demonstration available.

**Pasteurization.** Recognized method to achieve class A pathogen reduction and vector attraction reduction criteria. Easy to certify biosolids as Class A. Excellent long-term odour control of treated material. Store treated material through winter months without biological regrowth. Chemical process independent of type of sewage sludge. Can produce soil-like material. Nonrestrictive or less restrictive disposal options including beneficial reuse, landfill cover, disturbed land reclamation, land application, low capital and operation costs to achieve Class A biosolids, Turnkey processing and handling systems available, Equipment capable of producing both Class A or Class B biosolids, Rapid implementation for interim or permanent solution.

### Appendix 2. Vaporization moisture loss calculations

#### Calculations for determining the moisture loss and the final weight of lime-treated poultry manure

Values were taken from table 8 and rounded. The example assumes 100g wet manure (74% moisture) treated with 30g quicklime.

	CaO	Ca(OH) <sub>2</sub>	Water	Dry Manure	Total
<b>Initial</b>	30	0	74	26	130
<b>After treatment*</b>	0	42	62	26	130
<b>Final**</b>	0	42	45	26	113

\*Theoretical, with no water loss by evaporation

\*\*Actual values from Table 8. These values were calculated from the equation

$40 = 100[(62-x)/(130-x)]$ , where x is the water lost from 130g treated material.

WHICH CLASS A STABILIZATION PROCESS IS MOST  
ECONOMICAL: LIME STABILIZATION, COMPOSTING  
OR THERMAL DRYING?

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April 8, 1996  
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# Which Class A Stabilization Process Is Most Economical: Lime Stabilization, Composting or Thermal Drying?

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## Abstract

Solids stabilization is important to the reliable performance of any wastewater treatment plant (WWTP). The goal of solids stabilization is the reduction of odors, pathogens, and putrescibility of the solids. An ideal stabilization process converts raw wastewater solids to a stable product compatible with the chosen beneficial use/disposal method at least possible cost.

The USEPA Part 503 Sludge Regulations require stricter biosolids stabilization criteria. Some existing WWTP's using conventional methods may be unable to meet the stabilization criteria. Other municipalities have elected to use a superior Class A biosolids stabilization process that offer major advantages over Class B stabilization processes. Some advantages of using a Class A stabilization process includes easier compliance, less monitoring and recordkeeping, less odor in the final product and maximum flexibility for beneficial use/disposal and marketing options. Class A biosolids can be land applied or distributed and marketed Without the restrictions associated with Class B biosolids.

This study evaluated three commonly used Class A stabilization processes: lime stabilization, aerated static pile composting and thermal drying. The study includes a detailed analysis of capital, annual and present worth costs of these Class A process for generic 10, 20, 40 and 60-MGD WWTP's. For each size WWTP, lime stabilization had the lowest present worth costs, followed by the composting and thermal drying processes. The study also includes process and equipment descriptions, representative installation lists, and noneconomic advantages and disadvantages of each of the three selected Class A stabilization processes.





Fig. 1 CLC Mobile lime treatment plant, Agassiz, B.C.



Fig. 2 Loading blending hopper with fish waste.





Fig. 3 Loading dairy manure.



Fig. 4 Mixed dairy manure and lime.





Fig. 5 Delivery conveyer.



Fig. 6 Measuring temperature of the processed fish waste and lime.





Fig. 7 Ground fish waste pre-treatment.



Fig. 8 Processed chicken manure with lime.