CHARACTERIZATION OF MANURES FROM FISH CAGE FARMING IN CHILE

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ABSTRACT

This study aims to characterize salmonid (salmon and trout) manures and, to determine their potential use in agricultural soils. Sampling was carried out below salmon and trout cages in farms located in lakes and in the sea in the South of Chile during 2002-2003. Manure was analyzed for DM, pH, OM, macronutrients, micronutrients and heavy metals. Results showed a high variability between samples and differences between sea and lake manure. In general, DM contents were low averaging *c.* 12-15%. Manures showed low OM contents with values < c. 15% and a neutral pH (*c.* 7.0). Both manures had low total N contents (on a dry weight basis) with values of < 0.9%, of which >75% was in the organic form. On a dry weight basis lake manure showed high contents of P (1.56%), Ca (3.89%), Fe (27,948 ppm), Mn (446 ppm), Al (31,789 ppm), As (5.13 ppm), Cd (1.04 ppm), Cr (18.8 ppm), Ni (12.3 ppm), Pb (3.5 ppm) and Zn (393 ppm). Sea manure had high contents of Mg (1.65% ppm), K (0.63%), Na (11.8%) and Cu (89 ppm). Heavy metal contents were below the limit established by Chilean legislation for sewage sludge. Salmonid manure had low nutrients and heavy metal contents and as a potential use in agricultural soils, which could reduce the risks of water pollution on sea and lakes from the fish farming industry.
Keywords: *salmonid manure, nutrient contents, fish farming wastes.*

INTRODUCTION

Chile is the main salmonid producer in the world, generating important income for the national economy. Salmonid farm cages located in the sea and lakes produce large quantities of organic waste. This material can accumulate on the seabed or lakebed below or near the net cage, as well as be suspended in the water column. Aquaculture waste consists primarily of soluble metabolic products as well as solids presents in the form of faeces and uneaten feed (Thorpe and Cho, 1995). In Chile, a study showed that for each ton of salmon produced, the equivalent of *c.* 1.4 t of waste are generated. From this *c.* 1.2 t are solid wastes, with 20.5 kg of total P and 42.6 kg of total N (Rodriguez, 1993). This author also stated that 78% of the P was in the solid fraction and 22% in a soluble form. In contrast, for N 80% was in the soluble form and only 20% in the solid fraction.

This organic material represents a potential risk of contaminating the wider environment. A management practice to reduce this risk could be to recover this waste from the sea or lake bed under salmonid cages and apply it to farmland. Therefore, characterization of these manures will be necessary in order to know their nutrients value as fertilizers and to determine any potential adverse effects on crops and pastures. There is a lack of information about the macro and micronutrients contents and heavy metal of these materials. In addition, most studies have focused on fish raceways on land-based facilities (e.g. Naylor et al, 1999), therefore differences in their composition could be expected. This study aims to characterize salmonid manures and, to determine their potential use in agricultural soils.

MATERIAL AND METHODS

Manure was collected by divers using a core sampler from the bottom of the cages, in the sea or lake bed. Sampling was carried out below salmon and trout cages in farms located in lakes and the sea in the South of Chile during 2002-2003. A total of 3 L of manure was collected from different parts of the 'waste settling zone' beneath fish cages. The samples was stored in plastic containers and refrigerated once they reached the laboratory (< 4ºC). A fraction of each manure sample was oven dried at 105°C. Analyses were carried out at the National Institute for Agricultural Research laboratories. Dry matter (DM), pH, organic matter (OM), and total macro nutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), ammonium (NH_4-N), iron (Fe), manganese (Mn) and aluminum (Al) were determined according to the methodologies revised by AOAC (1984) and Sadzawka (1990) (Table 1). The levels of the elements arsenic (As), cadmium (Cd), copper (Cu), chromium (Cr), nickel (Ni), lead (Pb) and zinc (Zn) were determined by the methodology revised by EPA (1996) (Table 1).

The chemical and physical data gathered were ordered, tabulated and analyzed statistically, the average and standard error being calculated for each parameter.

Table 1. *Laboratory analysis and methodology used in this study.*

Parameter	Methodology
Dry matter	Gravimetric method
pH	Potentiometric method
Total N	Kjeldahl method
NH_4-N	Direct distillation
Total P	Visible spectrophotometer
Na and K	Atomic emission
Ca, Mg, ,Fe, Mn, Al, Cd, Cu, Cr, Ni, Pb, and Zn	Atomic absorption

RESULTS AND DISCUSSION

In general, nutrient contents were low in both manures being similar to those reported for animal manures and sewage manuress elsewhere (e.g. MAFF, 2000). Both salmonid manuress showed a high variability in their chemical contents, which is common for most of the organic wastes. For fish manure this variability has been associated with management practices, species and size of the fish, feed and feeding systems and water flow dynamics (e.g. Westerman et al., 1993).

Both manures had low DM contents averaging *c.* 12-15% (Table 2). Manures collected were highly diluted, which could results in a high disposal cost for agricultural land applications. Manures showed low OM contents with values of <15% and a neutral pH (*c.* 7.0). Salmonid manures had much lower OM contents than other types of organic residues such as cattle manure or sewage sludge. This low OM content for sea and lake bed manures could be the result of contamination with sand due to water currents under the sea or lake.

Both manures had low total N contents (dry weight basis) with values of < 0.9%. Approximately 75% and *c.* 95% of the total N content was in the organic form, for the lake and sea manures, respectively. The low content of the soluble N form in salmonid manure is probably the result of loss of soluble N in the water column before it reaches the sea or lake bed. Fish excrete the majority of their nitrogenous wastes across the gills as ammonia (e.g. McDonald and Wood, 2002).

Lake manure showed higher contents of P and Ca than sea manure. In contrast, sea manure had higher K, Mg and Na contents than lake manure. The high concentration of Na in sea manure could be attributed to the natural concentration of this nutrient in sea water. On manure application to farmland this high concentration could be a limitation depending on the susceptibility and demand of the crop.

Table 2. *Macronutrient contents in salmonid manures (dry weight basis).*

Origin	N total (%)	P (%)	K (%)	Ca (%)	Mg (%)	Na (%)
Lake manure	0.94	1.56	0.06	3.89	0.40	0.24
	(0.076)	(0.342)	(0.006)	(0.729)	(0.018)	(0.012)
Sea manure	0.41	0.81	0.63	2.62	1.65	11.80
	(0.031)	(0.084)	(0.061)	(0.189)	(0.120)	(1.246)

( )= values between parenthesis are standard error of the mean.

In general, lake manure showed higher micronutrient contents than sea manure (Table 3). High concentrations of Fe and Al were observed in both manures, especially in lake manure. These high values may be associated with the high background contents of the lake sediments originating from the volcanic soils of the South of Chile (Sadzawka and Carrasco, 1985). A similar high level of Fe and Al has been reported by Salazar et al. (2003) for dairy slurry. It is important to mention that most of the Al was in a 'non exchangeable' form. Therefore, if manure is applied to farmland it should not affect crops negatively.

Heavy metal concentrations were low (Table 3), being below the limit established by Chilean legislation for sewage sludge. Sea manure had higher As, Cd, Cr, Ni, Pb and Zn concentration than lake manure. Both heavy metal concentrations were higher than those found by Naylor et al. (1999) for trout manure collected from raceways and within the range of those reported for dairy and beef cattle by Nicholson et al. (1999).

Table 3. *Micronutrient and heavy metal concentration in salmonid manure (dry weight basis).*

Origin	Fe (ppm)	Mn (ppm)	Al (ppm)	As (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Zn (ppm)
Lake	27948	446	31789	5.13	1.04	18.8	45	12.3	3.50	393
manure	(1345.4)	(29.5)	(1297.6)	(0.581)	(0.149)	(0.71)	(0.9)	(0.55)	(0.22)	(70.3)
Sea	10885	101	10506	3.02	0.55	14.8	89	7.6	2.53	188
manure	(850.3)	(8.1)	(1317.0)	(0.144)	(0.036)	(1.02)	(11.6)	(0.50)	(0.04)	(13.4)

( )= values between parenthesis are standard error of the mean.

CONCLUSIONS

Manures from salmonid farm cages located in the sea and in lakes in the South of Chile had low nutrients and heavy metal contents. These organic residues have a potential use as fertilizers in agricultural soils, which could reduce the direct risks of water pollution from the fish farming industry.

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