Odour Control and Waste Management for Intensive Livestock and Dairying using Effective Microorganisms (EM)

HortResearch and Biological Husbandry Unit

Abstract

Research on EM extension and addition of extended EM using molasses and/or dairy effluent were conducted in the lab and field pond systems in order to treat dairy effluents. Results obtained showed that (1) EM extension was successful using molasses as well as high concentrated organic dairy effluents; (2) extended EM addition to dairy effluents can decrease COD and available phosphorus due to improved microbial activity; (3) extended EM solutions exhibited biological flocculation characteristics through increased sludge sedimentation; (4) addition of extended EM solution to anaerobic dairy effluents reduced the offensive odour.

Introduction

Effective Microorganisms (EM), developed by Prof. Teruo Higa, of the College of Agriculture at the University of the Ryukyus in Okinawa, Japan has been used widely such as for odour control in landfill, processing organic waste into fertilizers, leachate treatment, as well as urban and animal wastewater treatment. EM technology has been proven to be safe, low-cost, effective and easily utilized in environmental protection. In New Zealand, EM is produced with locally sourced microorganisms by the NZ Nature Farming Society, which has a primary focus on agronomic use.

In New Zealand, dairy herds typically graze pasture for most of the year. Cows are confined only during milking operations, a total time of from approximate 1.5 to 3 hours per day. The controllable manure waste from NZ dairy herds originates from this short period of dairy confinement, and comprises 6 to 12% of total daily production of manure. Manure from the dairy shed confinement is flushed away with water, and this, along with udder washwater, milking plant washwater, and any milk spillage constitute Dairy Shed Wastewater (DSW). Until the late seventies, most dairy farms in New Zealand discharged DSW untreated into the nearest waterway. Surface water quality in areas of intensive was considerably degraded, and catchment authorities (now Regional Councils) for the past 10-20 years have encouraged the installation of two-pond oxidation pond systems to treat DSW prior to discharge . However, reports on the performance in practice a two-pond system highlighted that effluent quality was very variable and often poor. Further, there has been increasing concern about the impact of other pollutants in DSW such as ammonia, phosphorus, pathogens etc., and the efficacy of two-pond systems in reducing the amounts of them in the effluent. Most effluent treatment work in New Zealand has focused on basic and mechanical system designs with a general reliance on microorganisms naturally present. The research presented was initiated to evaluate if EM technology can benefit New Zealand dairy effluent quality in-vivo and in treatment ponds.

The work is needed since dairy effluent currently poses significant environmental issues particularly in regard to water quality and nutrient and pathogenic bacteria contamination.

The aim of this research was to scope the potential for the microbial EM treatment to improve DSW by monitoring COD, selected nutrient loadings, sludge content and bacterial contaminants. To achieve this aim in a relatively short time period (6 weeks) with a limited budget, a 2-step approach was taken. The first involved three laboratory experiments and the second a preliminary field evaluation. The laboratory trials were set up to investigate nutritional requirements suitable for EM extension for use in DSW treatment. The preliminary field trial was to assess conditions in the field and variations between dairy farms, the treatment ponds, DSW contamination and variations thereof over time.

Fermentation experiment

Materials and methods

Unless otherwise described, all analytical methods have been based on the Hach system. An overview of the dairy farms participating in the trail is presented in Appendix 1.

EM extension

EM-1, obtained from NZNFS (New Zealand Nature Farming Society), was extended using molasses, dairy effluent and molasses-dairy effluent mixtures as described in Table 1. The dairy effluent consisted of an effluent mixture made up of equal rates (v/v) of DSW collected from the 10 farms in April 2003. The COD of this mixed dairy effluent was approximately 4570 mg/L.

Experimental design

The EM-1, molasses, dairy effluent and distilled water were mixed according to the series in Table 1. The different mixtures (200 mL) were put into 250 mL Erlenmeyer flasks ceiled with parafilm and incubated stationery at a temperature of about 19.5°. Treatments of each series were duplicated.

Table 1. Substrate amounts used in the EM extension experiment

Series and Treatment code	EM-1	Molasses	Dairy Effluent	Water
1. 5 EM1 + 5 Mol	5%	5%	0%	90%
2. 5 EM1 + 5 DE	5%	0%	5%	90%
3. 2 EM1 + 5 DE	2%	0%	5%	93%
4. 2 EM1 + 5 Mol + 5 DE	2%	2%	5%	91%
5. 2 EM1	2%	0%	0%	98%
6. 5 EM1	5%	0%	0%	95%

The pH and total number of bacterial colony forming units (CFU) were measured 6 and 5 times, respectively, in 1-3 day intervals during the 10-day incubation period.

Bacterial CFU were determined diluting (10 fold dilution steps) a 0.5 mL subsample and enumerating (in duplicates) the dilutions (10^{-2} to 10^{-7}) on potato dextrose agar (Merck) after 2 days incubation at 20°C.

Result and discussion

Figures 1&2, show pH and bacterial CFU changes, respectively, during the incubation period. Successful EM extension is indicated by a decrease in pH to approximately 3.5. The pH did not decrease sufficiently in the 2% and 5% EM-1 + 5% dairy effluent treatments. Molasses alone and/or in combination with dairy effluent was required to achieve successful EM extension. The results of the microbial counts showed that all treatments reached maximum CFU after 7-10 day incubation. Based on the pH and microbial results, EM can be extended on molasses and/or molasses + dairy effluent, with the latter being more cost-effective (as less molasses used) plus the potential advantage of microbial adjustment to the dairy effluent. EM extended Series 1 (5 EM1 + 5 Mol) and Series 4 (2 EM1 + 2 Mol + 5 DE) as described in Table 1, were chosen for EM extended inoculations in the subsequent experiments.

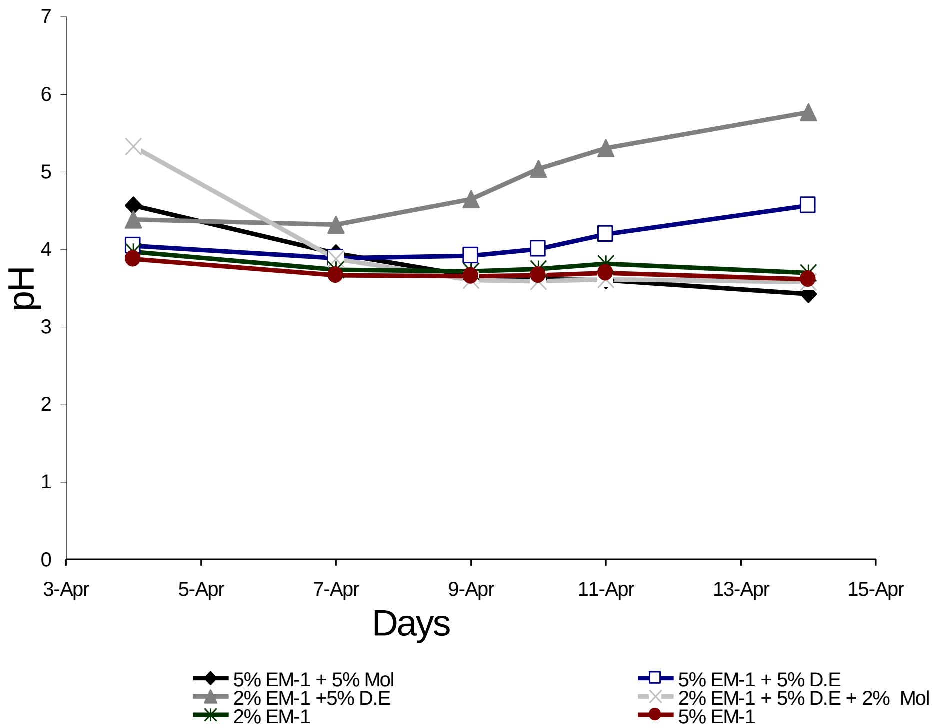

Figure 1. pH measurements for the different EM extensions (see Table 1) during 10 days incubation at 19.5°C.

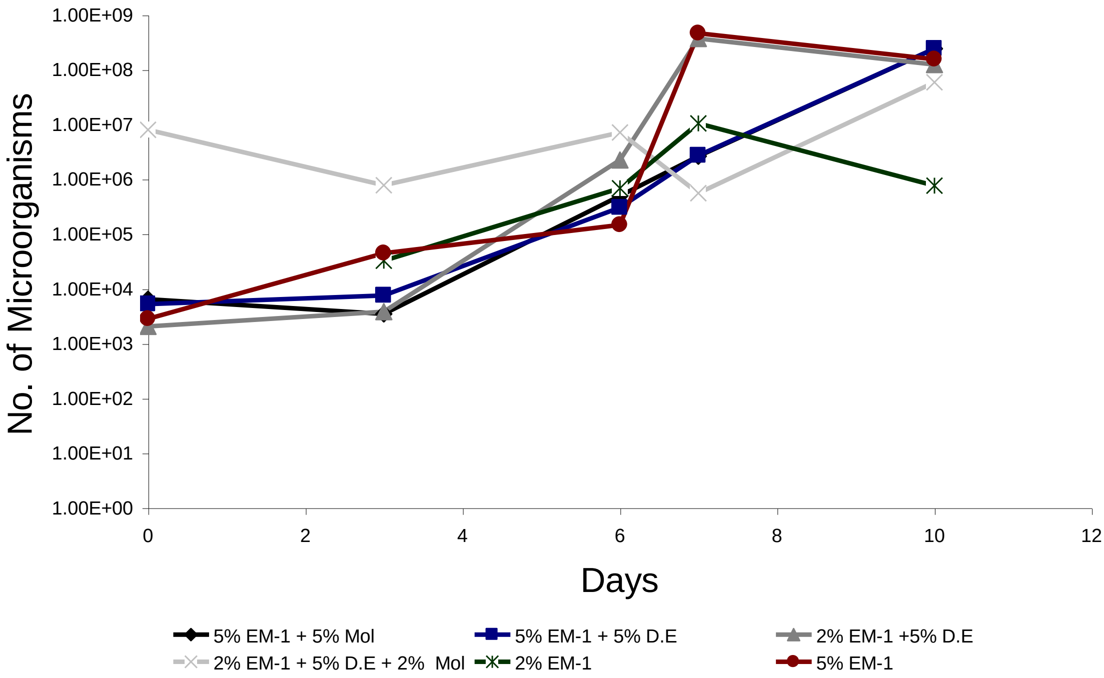

Figure 2. Bacterial colony forming unit (CFU) counts for the different EM extensions (see Table 1) during 10 days incubation at 19.5°C.

Dairy effluent treatment using extended EM

Materials and methods

The purpose of these two laboratory experiments was to determine the effect of EM extended on dairy effluent. Treatments assessed included the type of EM extended used (ie extension based on molasses vs molasses + dairy effluent), and the concentration of the extended EM added to the DSW. The DSW used in this experiment consisted of the 10 farms dairy effluent mixture as described above. This experiment was designed to not only compare the treatment efficacy using different EM extended additions as well as extension methods but also to supply operational evidence for the practical dairy effluent treatment in dairy farms. Table 2 lists the different treatment combinations tested. For Series 9-11 the ratio of ingredients was

EM-1: molasses: water = 5%: 5%: 90%;

whereas for Series 12-14 using dairy effluent (mixture of 10 farms) based extension the ratio of ingredients was

EM-1: molasses: dairy effluent: water= 2%: 2%: 5%: 91%

In the second laboratory experiment, the two dairy farms Farm 4 (F4) and Farm 10 (F10), showed relatively high COD readings, thus these 2 farms were selected to further study the effect of EM extended treatments in a sub-experiment (Table 2).

Table 2. Dairy effluent treatments (type and concentration of extended EM) for the two laboratory experiments

Series and Treatment code	Dairy effluent (mL)	EM-1 (%) Prior to extension	EM extended used[1]	Shaken at sampling
Lab experiment 1				
8. Nil	1000	0	Nil	Yes
9. Mol 1mL	1000	0.005	Series 1	Yes
10. Mol 2mL	1000	0.01	Series 1	Yes
11. Mol 6mL	1000	0.03	Series 1	Yes
12. Mol + DE 2.5mL	1000	0.005	Series 4	Yes
13. Mol + DE 5mL	1000	0.01	Series 4	Yes
14. Mol + DE 15mL	1000	0.03	Series 4	Yes
Lab experiment 2				
15. Nil	250	0	Mil	No
16. Mol 2.5mL	250	0.05	Series 1	No
17. Mol 5mL	250	0.01	Series 1	No
18. Nil	250	0	Nil	No
19. Mol 2.5mL	250	0.05	Series 1	No
20. Mol 5mL	250	0.01	Series 1	No

[1]Please refer to Table 1 for detail

In the first Laboratory Experiment, all effluent treatments were incubated stationary for 10 days at 19.5°C in the dark. Measurements listed below, were taken regularly in 1-2 day intervals except for odor which was monitored at the beginning and at the end of the experiment only. Prior sampling, flask were shaken to suspend the soluble solids. Samples were homogenized using an Ultra Turrex prior analysis (except for TSS and VSS measurements).

In the second Laboratory Experiment, effluent treatments were also incubated stationary for 10 days at 19.5°C in the dark. Only COD, available P, odor, pH and conductivity measurements were taken. Prior sampling, flask were not shaken.

Measurements

All measurements are based on the Hach system unless otherwise stated

BOD_5: respirometric method (using the BOD Trak apparatus)

COD: manganese reactor digestion method

TSS: Total Suspended Solids (total nonfilterable residue, 105°C): gravimetric method based on 50 mL subsample

VSS: Volatile Suspend Solids (500°C): gravimetric method based on TSS sample

Conductivity: direct measurement method using conductivity probe

pH: direct measurement using portable pH meter

TN: Total Nitrogen: TNT Persulfate Digestion method

TP: Total Phosphorus: Phos Ver 3 with acid persulfate digestion

Avail P: Available Phosphorus **:** Phos Ver 3 with HACH DR/2010 Portable datalogging spectrophotometer

Odor: sniff test

Microorganisms: Ecoli, Salmonella and Coliforms were enumerated on Chromcult® Coliform Agar (Merck) for 0.01 mL, 0.005 mL and/or 0.001 mL homogenized subsamples.

Results and discussion

In this section, results on the measurements taken are presented for Lab Experiments 1 and 2 sequentially in the following order: COD, available P, TSS/VSS, microbial counts, pH and conductivity. Total N and available N measurements were compromised by the presence of high chloride and calcium levels. The Hach analytical system could not be adjusted to reproducibly measure Total N or available N. Thus results cannot be presented in this document. Different methods will be required to measure total and available N.

COD. Effects of different EM extension methods and concentrations added on COD are shown in Table 3 and Figure 3. It can be seen that addition of EM extended solutions to dairy effluents could reduce COD by 15-48% compared with the nil control and was effective within one day. Higher rates of EM addition tended to result in greater reduction of COD but while this was apparently the case in the EM treatments that did not include dairy effluent in the initial EM expansion it was not clear in the other treatments. Dairy effluent added during the expansion of EM in preparation for this experiment appeared to have no significant effect on the effectiveness of the expanded EM in controlling COD.

The reduction in COD due to EM treatment lasted the duration of the experiment but all samples exhibited a rise in COD after the 8 day observations. This may have been due to increasing readily oxidisable nature of decomposing material at this stage. Although the lift of COD appeared to be less in the EM treatments (COD levels ended up around 7% less than near the start of the experiment compared to 58% above that level for the nil control) it may be worth assessing in future experiments if further EM should be added at such a stage to help minimize COD.

Table 3. Lab experiment 1: The effect of EM extension method on reduction of COD level of dairy effluents

	Days					
Series and Treatment code[1]	**0.2**	**1**	**2**	**3**	**8**	**10**
8. Nil	4416^{ns}	5234**	4764**	4445**	3163*	6994***
9. Mol 1mL	4816	3395	3882	3528	2848	4602
10. Mol 2mL	4609	3708	4202	4295	2755	4069
11. Mol 6mL	3288	2568	3535	2781	1814	2294
12. Mol + DE 2.5mL	4042	4122	3482	3422	2788	2808
13. Mol + DE 5mL	3902	3128	3095	3642	3495	4002
14. Mol + DE 15mL	3022	3415	4336	3909	2468	3962

[1] described more detailed in Table 2

ns: Nil treatment not statistically significantly different ($p>0.1$) from the EM treatments (z test)
*,**,***: Nil treatment statistically significantly different ($p<0.1$, $p< 0.05$, $p<0.01$ respectively) from the EM treatments (z test)

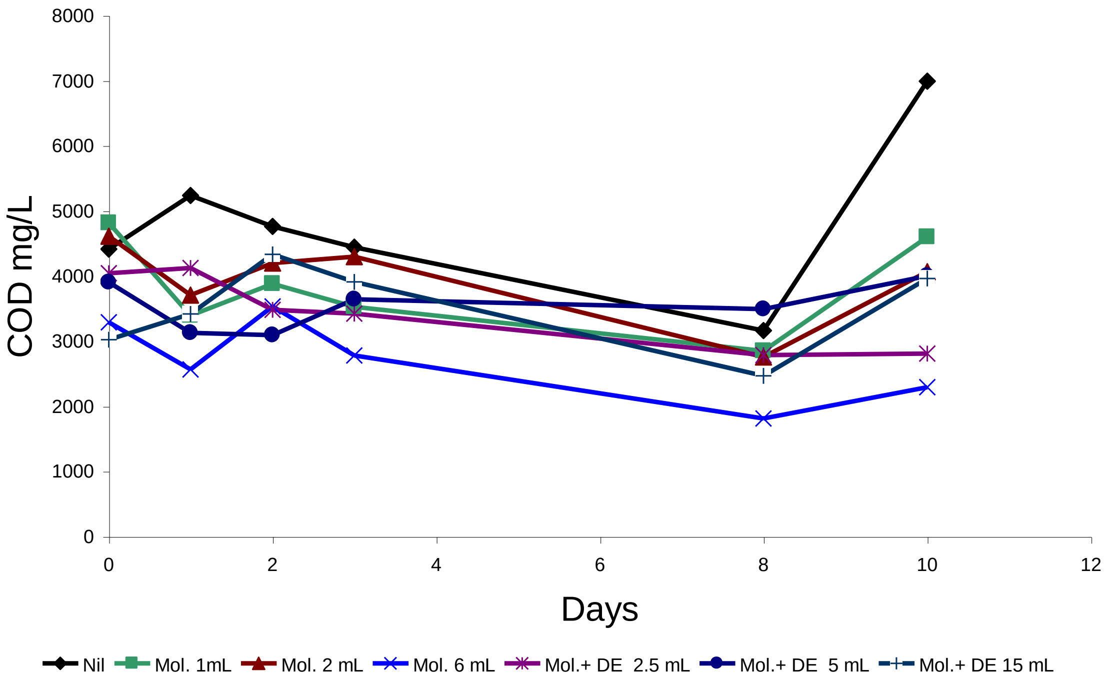

Figure 3. Lab experiment 1: COD (mg/L) measurements for dairy effluent treated with different EM extended preparations at different concentrations. For treatment descriptions please refer to Table 2.

For the second laboratory experiment, anaerobic conditions were maintained throughout the first six days after which they were occasionally opened for observation. the reduction of COD due to EM treatment (20-50% reduction compared with the nil control) was clear and statistically significant ($P<0.05$) for both farm sources at the Day 6 observation but the difference was less apparent by Day 7 (after the containers had been opened for the first sampling) in the Farm 10 samples and not apparent at all in Farm 4 samples as shown in Table 4 and Figure 4. The addition of the higher EM extended application rate for both two dairy farms had higher COD removal than the lower EM extended application rate (a regression analysis was significant, $p<0.01$). The results indicated that all treatments headed towards a similar level of COD but that the EM treatments reached that level sooner, at the higher rate these treatments in fact temporarily reached low levels. In NZ dairy farms, dairy effluents usually remains in anaerobic ponds for several days. The results demonstrate that addition of EM extended solutions to an anaerobic pond could reduce COD. The reasons for the drop off of relative effect at Day 7 whether related to opening the jars or not requires further investigation.

Table 4. Lab experiment 2: The effect of EM addition at two concentrations on COD levels of dairy effluents in anaerobic condition

Series and Treatment code[1]	Days				
	0[2]	6	7	8	11
15. Nil (Farm 4)	14325	13400	10230	10210	10150
16. Mol 2.5mL (Farm 4)	14325	11400	10590	10610	10280
17. Mol 5mL (Farm 4)	14325	7400	10580	10500	10200
18. Nil (Farm 10)	16946	16150	10620	10480	10560
19. Mol 2.5mL (Farm 10)	16946	10750	8880	10590	10760
20. Mol 5mL (Farm 10)	16946	6700	8720	10580	10520

[1] described more detailed in Table 2

[2] The zero day measurement was from measured once for each farm source from the samples that were then split for each treatment

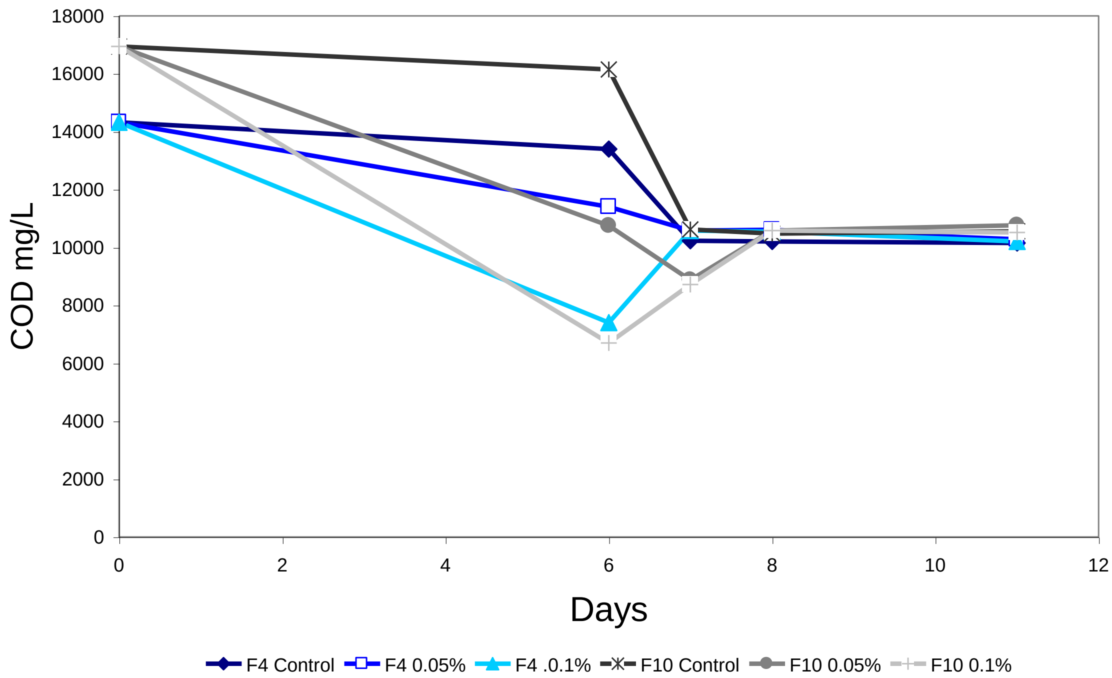

Figure 4. Lab experiment 2: COD (mg/L) measurements for two farms with high original COD treated with EM extended. For treatment descriptions please refer to Table 2.

Available P. No obvious effect on available P was discerned. Figures 5 and 6 show the high variability present.

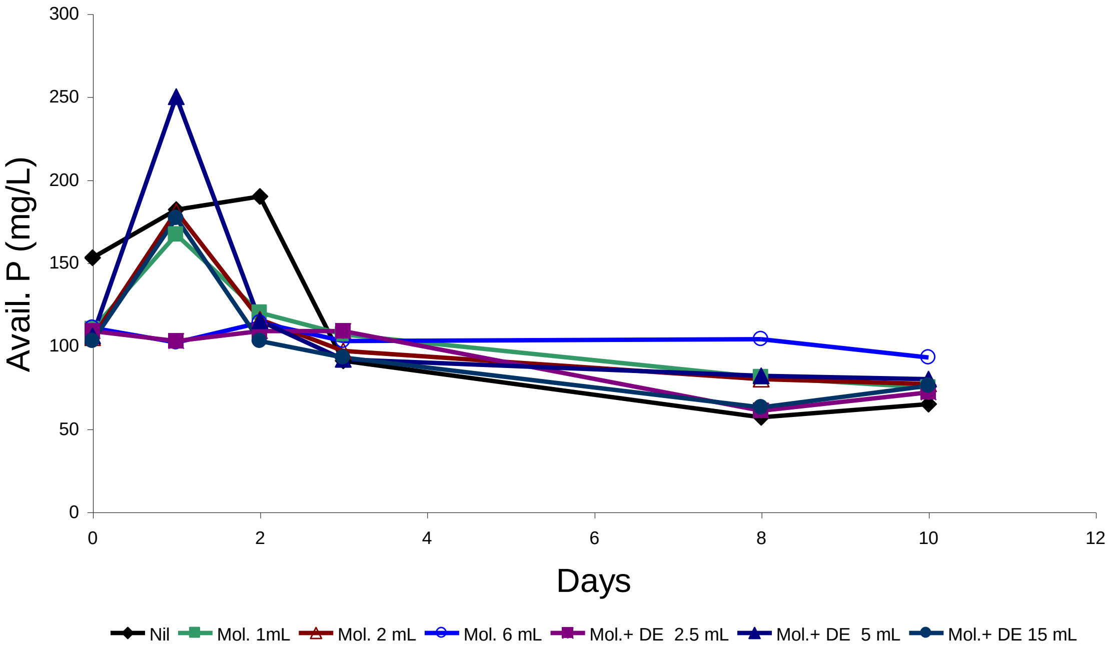

Figure 5. Lab experiment 1: Available P (mg/L) measurements for dairy effluent treated with different EM extended preparations at different concentrations. For treatment descriptions please refer to Table 2.

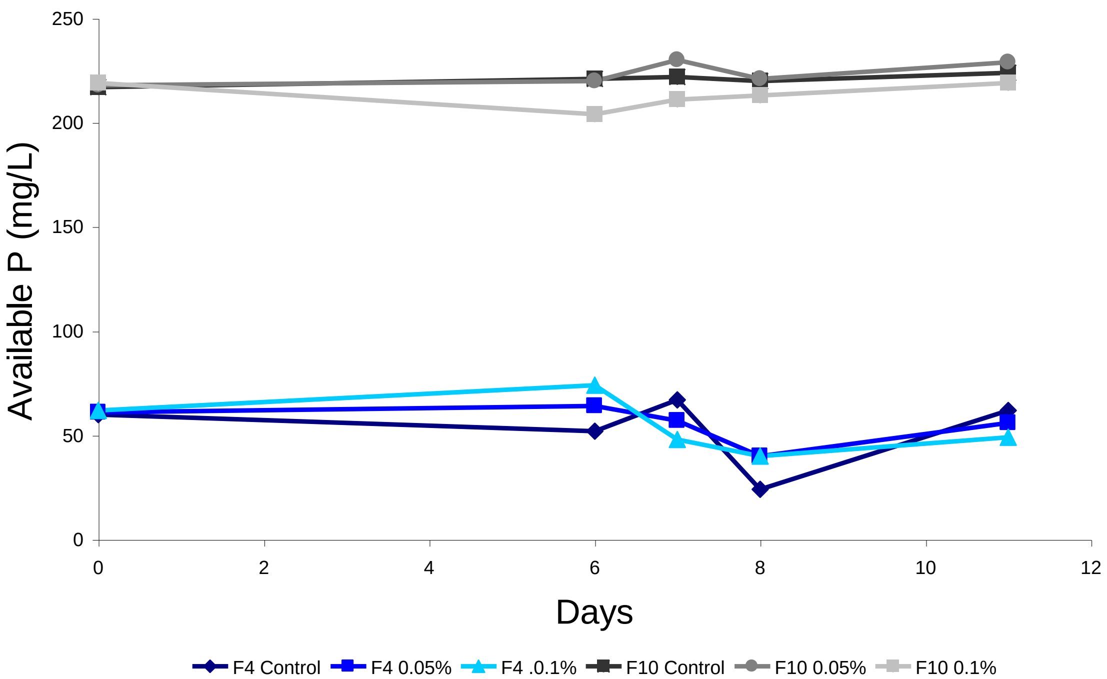

Figure 6. Lab experiment 2: Available P (mg/L) measurements for two farms with high organic matter treated with EM extended. For treatment descriptions please refer to Table 2.

TSS/VSS. Table 7 shows the amount of TSS and VSS (mg/L) measured for the Lab Experiment 1. Effect of different EM-1 addition ratios and incubation methods on TSS and VSS in dairy effluents. Figure 7 shows that at the beginning of reaction the values of TSS and VSS in the EM extended treatments are much lower than those in the nil control. Over time, the TSS and VSS measures of the dairy effluent treatments gradually increase, particularly TSS values go up. This increase is generally greater in EM extended treatments than in the nil-control. This may be explained by the activity of certain microorganisms (such as Microzyme in the EM extended) which can excrete flocculent material, thereby improving the settlement performance of sludge.

Table 7. Lab experiment 1: TSS and VSS (mg/L) of EM activated solution to treat dairy effluents

	Days					
Series and Treatment code[1]	**0.2**	**1**	**2**	**3**	**8**	**10**
TSS						
8. Nil	6.95	n.m.	n.m.	7.37	9.86	7.73
9. Mol 1mL	4.5	n.m.	n.m.	8.12	9.06	9.97
10. Mol 2mL	4.83	n.m.	n.m.	6.56	9.34	9.01
11. Mol 6mL	2.75	n.m.	n.m.	10.44	10.73	10.85
12. Mol + DE 2.5mL	3.04	n.m.	n.m.	10.22	3.48	9.92
13. Mol + DE 5mL	3.12	n.m.	n.m.	8.89	8.08	8.36
14. Mol + DE 15mL	2.31	n.m.	n.m.	8.71	10.51	8.04
VSS						
8. Nil	3.92	n.m.	n.m.	3.38	5.28	4.02
9. Mol 1mL	2.63	n.m.	n.m.	3.68	4.62	5.29
10. Mol 2mL	2.81	n.m.	n.m.	2.95	1.50	4.75
11. Mol 6mL	1.65	n.m.	n.m.	4.67	5.69	5.66
12. Mol + DE 2.5mL	1.78	n.m.	n.m.	4.66	1.65	5.27
13. Mol + DE 5mL	1.59	n.m.	n.m.	3.99	4.29	4.59
14. Mol + DE 15mL	0.74	n.m.	n.m.	3.89	9.34	4.40

[1] described more detailed in Table 2

n.m. = no measurement taken on this day.

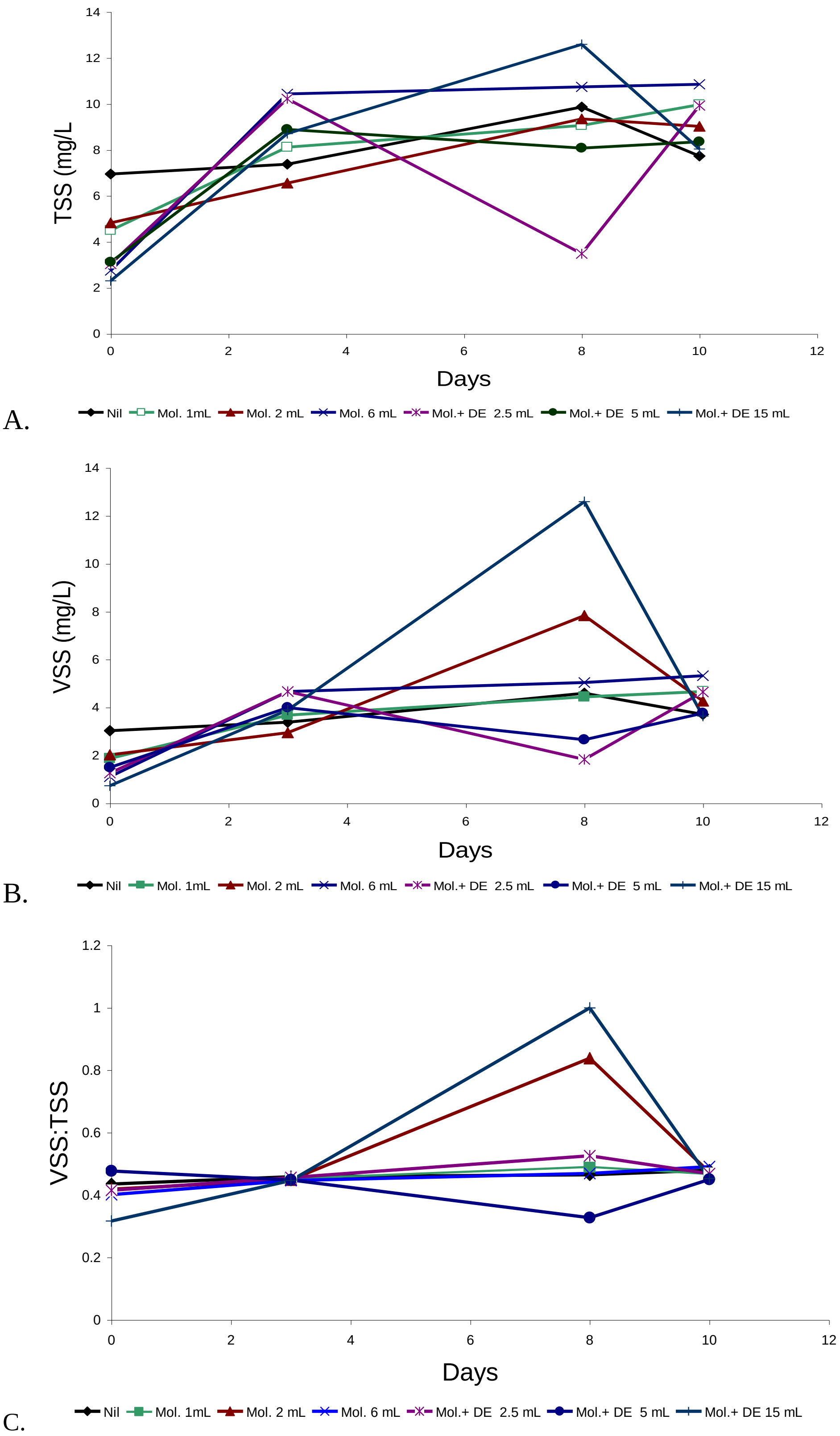

Figure 7. Lab Experiment 1: VSS (A), TSS (B) and VSS:TSS (C) measurements for dairy effluent treated with different EM extended preparations at different concentrations. For treatment descriptions please refer to Table 2.

Odor. Tables 8 and 9 demonstrate the effect EM extended treatments on odor using a sniff test for the Lab experiments 1 and 2, respectively. In both experiments, all EM extended treatments removed offensive odor. The smell changed from the typical strong-pungent dairy effluent smell (nil control) to a rather sweet composting/mushroom smell.

Table 8. Lab experiment 1: Odor control by EM activated solutions used to treat dairy effluents. The scale ranges form offensive (++++) to non-offensive, sweet (-) odor.

	Days					
Series and Treatment code[1]	**0.2**	**1**	**2**	**3**	**8**	**10**
8. Nil	++++	n.m.	n.m.	n.m.	n.m.	+++
9. Mol 1mL	++++	n.m.	n.m.	n.m.	n.m.	-
10. Mol 2mL	++++	n.m.	n.m.	n.m.	n.m.	-
11. Mol 6mL	++++	n.m.	n.m.	n.m.	n.m.	-
12. Mol + DE 2.5mL	++++	n.m.	n.m.	n.m.	n.m.	-
13. Mol + DE 5mL	++++	n.m.	n.m.	n.m.	n.m.	-
14. Mol + DE 15mL	++++	n.m.	n.m.	n.m.	n.m.	-

[1] described more detailed in Table 2

n.m. = not measured

Table 9. Lab experiment 2: Odor control by EM activated solutions used to treat dairy effluents from two dairy farms. The scale ranges form offensive (++++) to non-offensive, sweet (-) odor.

	Days				
Series and Treatment code[1]	**0.2**	**6**	**7**	**8**	**11**
15. Nil	++++	++++	+++	+++	+++
16. Mol 2.5mL	+++	+	-	-	-
17. Mol 5mL	+++	-	-	-	-
18. Nil	++++	++++	+++	+++	+++
19. Mol 2.5mL	+++	+	-	-	-
20. Mol 5mL	+++	-	-	-	-

[1] described more detailed in Table 2

It can be seen from Table 9 that after 6 days an-aerobic incubation, treatments of adding EM extended could remove offensive odor. This effect on odor control could be due to the fact that addition of EM extended changes the microbial population dynamics in dairy effluents blocking the growth of offensive-odor producing bacteria such as Ecoli and Coliforms.

Microbial Counts. Overall, microbial counts (Ecoli, Choliforms, Salomonella) behaved similar in the nil control as in the different EM extended treatments, with some EM treatments reducing bacterial counts to 0 (or non-detectable) after 8 days incubation (Figure 8).

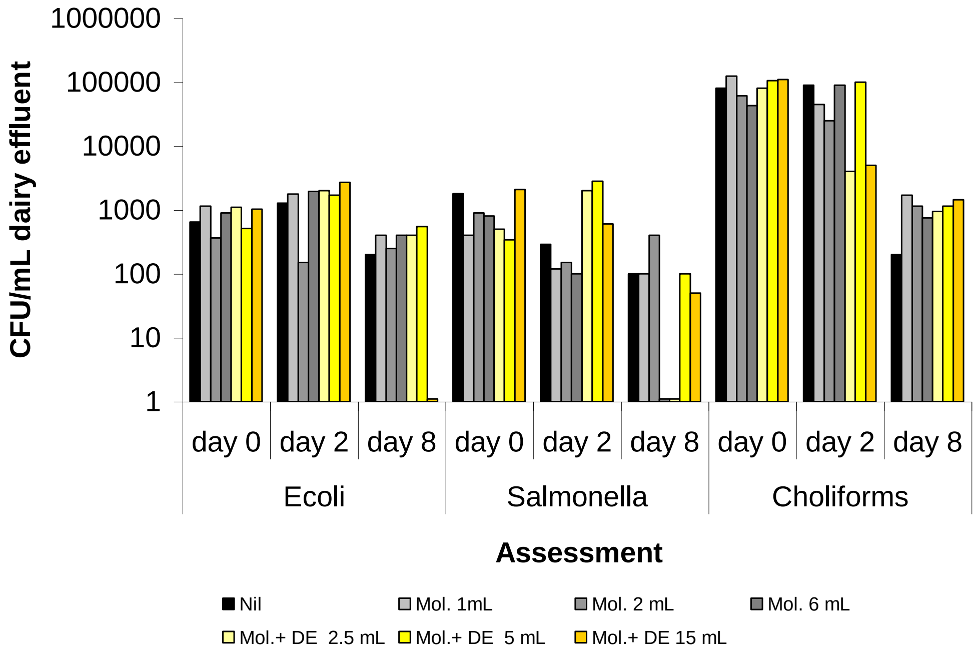

Figure 10. Lab Experiment 1: Microbial counts (CFU/mL dairy effluent) for dairy effluent treated with different EM extended preparations at different concentrations. For treatment descriptions please refer to Table 2.

pH and conductivity. During incubation, pH generally increases for all treatments in both laboratory experiments (Figures 9 and 10). Conductivity seems to be unaffected by EM extended treatments (Figure 11 and 12).

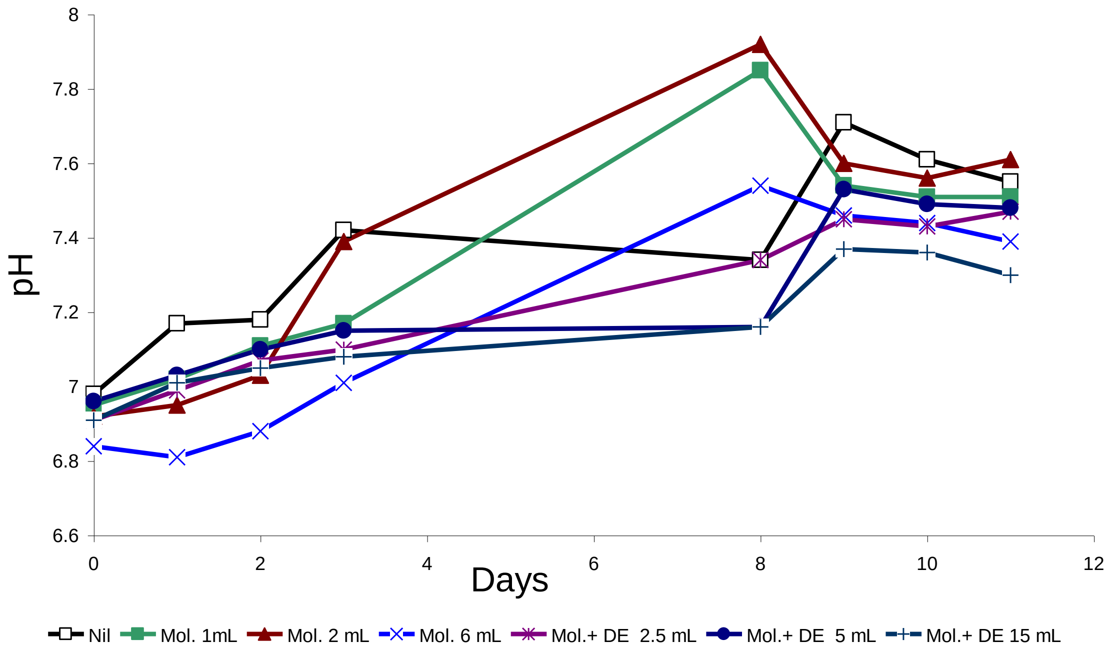

Figure 9. Lab Experiment 1: pH measurements for dairy effluent treated with different EM extended preparations at different concentrations. For treatment descriptions please refer to Table 2.

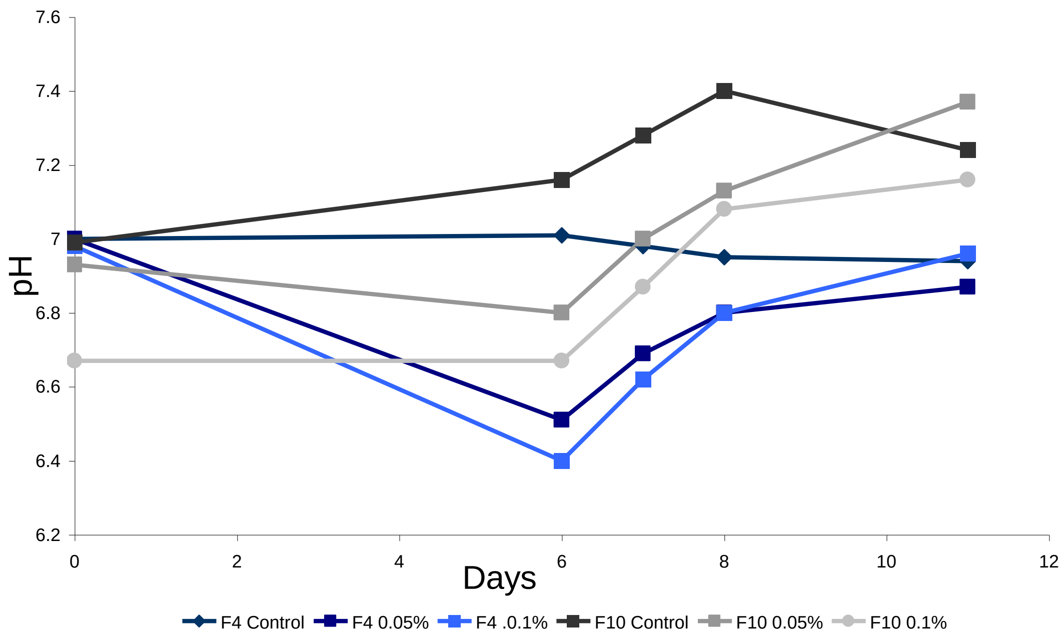

Figure 10. Lab experiment 2: pH measurements for two farms with high organic matter treated with EM extended. For treatment descriptions please refer to Table 2.

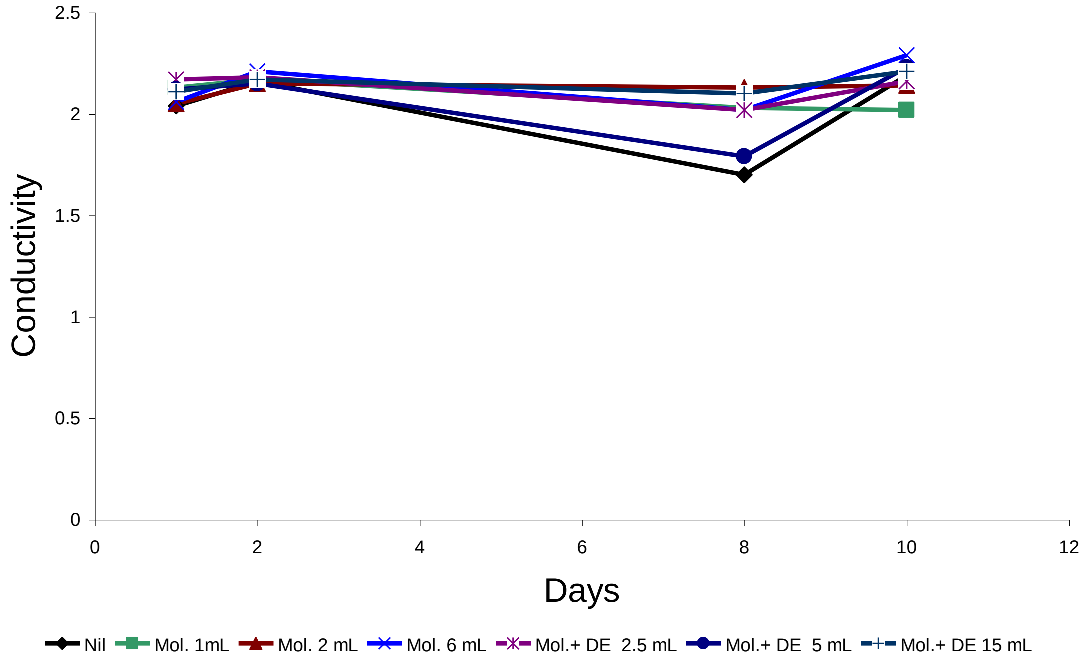

Figure 11. Lab Experiment 1: Conductivity measurements for dairy effluent treated with different EM extended preparations at different concentrations. For treatment descriptions please refer to Table 2.

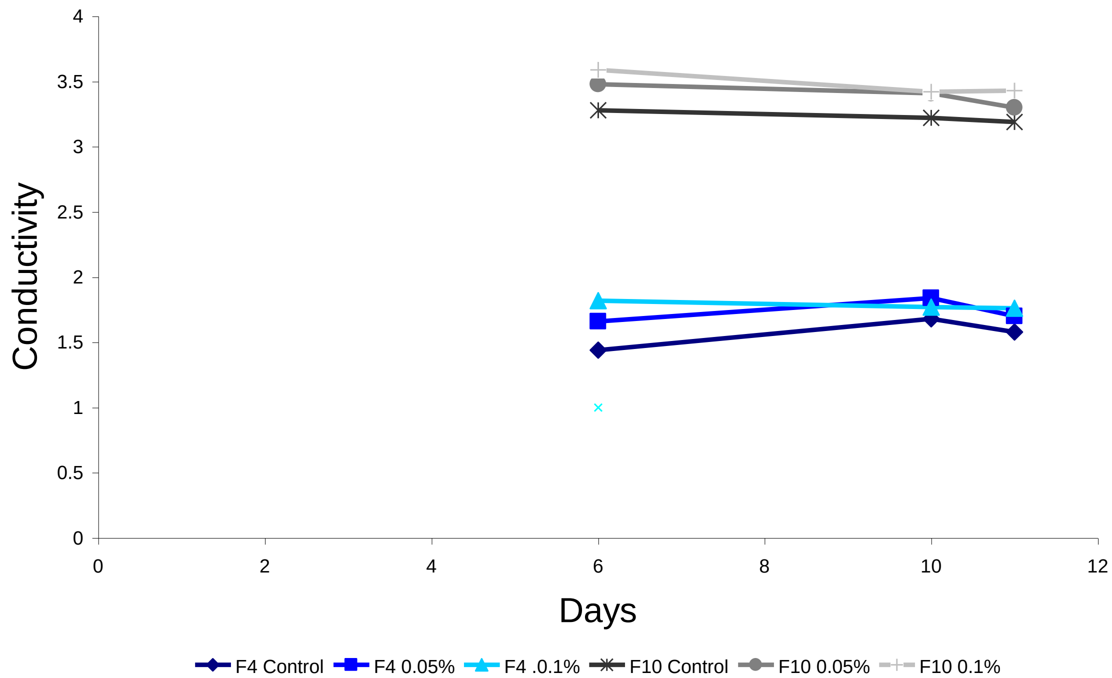

Figure 12. Lab experiment 2: Conductivity measurements for two farms with high organic matter treated with EM extended. For treatment descriptions please refer to Table 2.

Conclusions

EM extension is suitable using molasses and or a molasses-dairy effluent mixture, with the latter being more cost-effective. The substrates used for extension do not affect the efficacy of the extended EM as shown in the 2 laboratory experiments.

Overall, addition of EM extended to dairy effluent improved the ‘quality’ of the waste water, with the most noticeable effect on odor.

These experiments were set-up to explore the potential use of EM technology in New Zealand dairy farm effluent ponds. More research is required to (1) validate the positive trends observed and to (2) evaluate EM application in situ.

References

[1] Meng Fan-ping, Li Gui-fang, Li Ke-lin, A System Study on the Effective Microorganisms(EM) on the Removal of Pollutants from Domestic Sewage,Oct.1999,Urban environment & Urban ecology.

[2] Li WJ & Ni YC(1998) Application techniques of EM,1.st edn, Beijing:CAST Press.

[3] Shao XH, Liu DY,Zhu L&Liu XR(2000),Some problems and the sustainable development concerning wastewater treatment reused for agriculture irrigation in China .In: Proceeding of Chinese-Isreal workshop on water-saving Agiculture.

Acknowledgements

Authors are grateful to staffs in EM research organization Nanjing Co.Ltd for their excellent comments, suggestion and ideas. Special thanks go to Mr. Gu Fangshu, whose contributions to this research have been invaluable and the farmers who made their effluent ponds available.