Environmental Conditions and Resource Management in Smallholder Dairy Farms in Thailand. II. Effects of Dairy Wastes on Water and Soil

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ABSTRACT : The environmental conditions in smallholder dairy farms especially the effects of dairy wastes on waters anc soil were the main objectives of this investigation. Forty-three dairy farms from an older dairy cooperative (Nongpho Dairy Cooperative, NP) were compared with four dairy farms from relatively new dairy cooperative (Kamphaengsaen Dairy Cooperative, KS) for the quality parameters of water and soil samples during a 12-month period. Forty-three farms at NP were from three geographical areas and three levels farm crowdedness. The results from this study clearly showed that the waste waters from older dairy barns contained much higher levels of organic and inorganic substances which could create environmental pollution if not properly managed. The differences in waste water qualities due to areas and seasons were not significant, while waste water samples from crowded farms tended to contain higher averages of waste water parameters such as COD and BOD. Highly significant correlations between pairs of waste water parameters indicated that certain parameters can be used without the need for chemical analysis of some other parameters. The qualities of well water on dairy farms as well as water samples from public waterways nearby indicated some contamination of dairy wastes such as manure. Storage and sun-drying of dairy manure on bare soil surface could result in the contamination of underground water and nearby water sources. Some recommendations from this study if implemented can prevent environmental pollution in smallholder dairy farms.
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Key Words : Smallholder Dairy Farms, Environmental Conditions, Water and Soil Qualities, Coefficient of Correlations, Waste Parameters

INTRODUCTION

More than ninety percent of dairy farms in Thailand were reported to be smallholder dairy with the total number of dairy animals per farm of less than 40 (Chantalakhana, 1994). Dairy cooperatives have been organized in order to provide central milk collection and cooling facilities for member dairy farms which are commonly situated around a milk collection center, usually not farther than 20 kilometer distance. Hence, in a long term there is a general tendency of increasing number of dairy farms as well as number of animals per farm within the same plot of land. Generally, due to lack of waste management and disposal systems on small farms, animal wastes, dirty water, as well as other farm wastes appeared to cause degradation of farm environmental conditions in a long term, especially affecting water and soil qualities in surrounding areas, and consequently could generate unfavorable effects on human health. Dairying in Thailand began about forty years ago, some older dairy cooperatives have been in operation for more than two or three decades, started with small number of dairy farms, and then expanded to several thousand member farms within the same area. There has never been a research investigation on environmental conditions of these smallholder farms. Therefore, this study aims to examine water and soil properties of older dairy farms as compared with that of relatively new dairy farms in order to observe possible environmental trends.

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MATERIALS AND METHODS

A. Sampling of experimental farms

Forty-seven smallholder dairy farms were used in this study, 43 farms from older dairy cooperative (Nongpho Dairy Cooperative, NP) as described by Skunmun et al. (1998) and 4 farms from a relatively new dairy cooperative (Kamphaengsaen Dairy Cooperative, KS). The older dairy farms ranged from 18±7 to 19±7 years of operation, while the new dairy farms only 8±3 years. The locations of the two groups of dairy farms were approximately 30 km apart with similar agro-ecological conditions. The NP farms were selected from 3 areas i.e. A = irrigated area, B = municipality area, and C = factory area ; and from each area a number of farms were selected according to 3 levels of farm crowdedness or density i.e. 1 = very crowded, 2 = crowded, and 3 = not crowded (see table 1).

Table 1. Number of experimental farms classified by areas and stock densities

Area	NP 1	NP 2	NP 3	KS
A	5	7	3	
B	4	6	4	
C	5	5	4	
Total	14	18	11	4
Ave. no. of year in operation	18±7	19±7	18±8	8±3

Crowdedness of sample farms was based on physical proximity to neighboring farms, stocking rates, location of dairy barns (e.g. barn under the house, barn attached to the house, barn being separated but close to the house, etc), and surrounding conditions. The classification of the degree of farm crowdedness was based on subjective judgement of the cooperative dairy extension workers and the researchers. It was anticipated that more crowded farms should have greater difficulty in disposal of animal wastes, hence, will be reflected by some waste parameters which were measured by chemical analyses of farm water and soil properties.

B. Water and soil sampling

1) Water samples consisted of water from three sources : waste water from dairy barn, well water, and water from public waterways passing near some sample farms.

Waste water: Waste water samples were collected from liquid-waste disposal ditch behind cow barn, where the ditch could be cement or earthen floor. One sample of waste water from each farm was collected every month during 12-month period (May 1996 to April 1997) for chemical analysis. The following waste water parameters were measured i.e. pH, EC (electrolytic conductivity), TS (total solid), COD (chemical oxygen demand), BOD (biological oxygen demand), NH_3-N (ammonia nitrogen), and NO_3-N (nitrate nitrogen).

Well water : Most smallholder dairy farms (63-77%) at NP and all farms at KS, obtained water supply from deep wells. The number of wells used to study the quality of water supply are shown in table 2. A water sample from each well was taken for chemical analysis three times within a year i.e. May (summer), July (rainy season), and January (cool season). The following chemical properties were measured : pH, EC, chloride, nitrate, hardness, total coliform, and faecal coliform.

Table 2. Number of sample farm wells with different depths

Farm	Depth of well (m)			Total
	6	20-30	32-50	
NP	1	5	7	13
KS	-	-	1	1

Water from public waterways : Water samples from public waterways were collected from four locations at NP. One sample from each location (small canal) was collected every month for 12 months (one year) for chemical analysis in order to measure the same set of waste parameters as that for waste water from dairy barns.

2) Soil samples from farm areas where farmers commonly used for drying and storing manure were collected once every season (May, August, January) from 16 farms at NP and 1 farm at KS for chemical analysis. The following soil parameters were measured : pH, EC, K, P_2O_5, total N, NH_3-N, and NO_3-N.

RESULTS AND DISCUSSION

A. Differences of waste water parameters between old and new dairy farms

The data on waste water parameters studied during a 12-month period in order to compare a group of small holder dairy farms (43 farms) from older (NP) with another group (4 farms) from new site (KS) consistently indicated that waste-water samples from the old farms (NP) were higher in every parameter than that of the new farms (KS), see figures 1 to 3 for TS, COD, and BOD. The analysis of variance (ANOVA) in order to test the difference between NP and KS is shown in table 3, where 4 groups of farms NP1 (very crowded NP farms), NP2 (crowded NP farms), NP3 (Not crowded NP farms), and KS farms (not crowded) were compared within months. Although the differences among groups were highly significant only for COD, but with prior background knowledges of the differences between NP and KS farms further lsd (least significant difference) test was carried out as shown in the same table. The results of lsd test indicated highly significant differences ($p<.01$) between NP and KS for EC, TS, COD, and NO_3-N, and significant differences ($p<.05$) for BOD, NH_3-N, and pH of waste water.

It can be seen that the waste water from older and more crowded dairy farms (NP) contained much higher

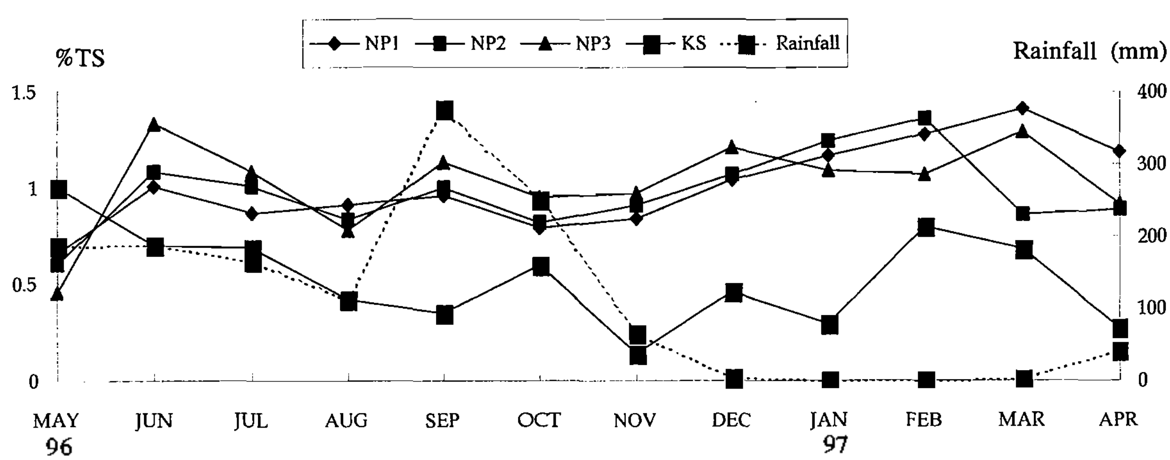

Figure 1. Monthly averages of TS (total solid) in waste water of dairy farms

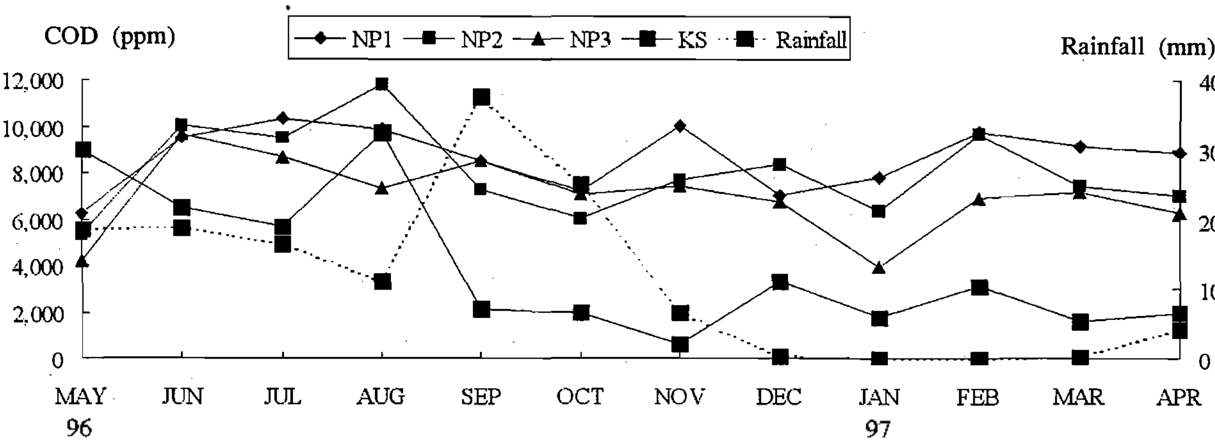

Figure 2. Monthly averages of COD in waste water of dairy farms

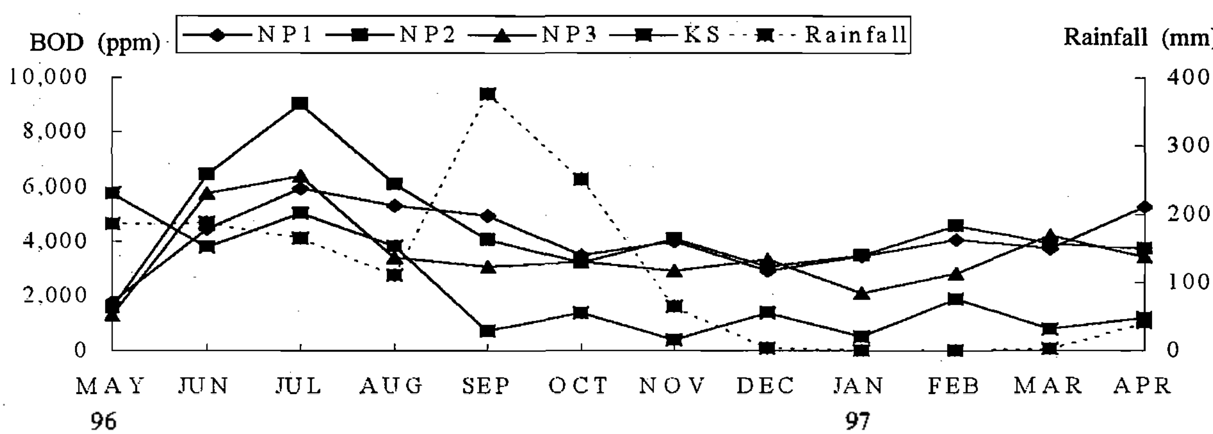

Figure 3. Monthly averages of BOD in waste water of dairy farms

Table 3. ANOVA of waste water parameters of NP and KS farms

SOV	df	MS						
		pH	EC	TS	COD(10^6)	BOD(10^6)	NH_3-N	NO_3-N
Months(M)	11	0.0891	127.99	1.27	71.33	84.16	1.20	470.77
Groups(G)/M	36	0.2708	78.28	0.56	42.49**	14.58	1.03	84.75
Farms	522	0.3116	59.17	0.53	24.56	10.95	1.24	85.44
Total	569							

Parameter	Unit	Average[1]				Significance[2]	lsd (0.05)	lsd (0.01)
		NP1	NP2	NP3	KS			
EC	ms[3]	10.79	10.70	10.51[4]	5.88	**	2.50	3.32
TS	%	1.006	0.961	0.998	0.534	**	0.238	0.313
COD	ppm	8.860	7.992	7.063	3.954	**	1.625	2.135
BOD	ppm	3.882	4.262	3.461	2.226	*	1.083	1.424
NH_3-N	ppm	847	837	743	286	*	365	480
NO_3-N	ppm	11.87	12.12	11.67	5.41	**	3.30	4.34
pH		8.03	8.00	7.97	7.76	*	0.183	0.240

[1] NP = Nongpho, KS = Kamphaengsaen.
[2] Difference between KS average and lowest NP average, * = p<0.05 and ** = p<0.01.
[3] ms = millisiemen.
[4] Averages with underline were not significantly different.

Table 4. ANOVA for waste water parameters of NP farms

SOV	df	MS			COD	
		pH	EC	BOD	df	MS (10^6)
Seasons (S)	2	0.073	20.6	116.7	2	21.4
Months (M)/S	9	0.113	154.0	77.7**	9	64.9
Areas (A)/M/S	24	0.412	117.2	14.3	24	34.3
Groups (G)/A/M/S	72	0.264	72.9*	16.3**	72	46.5**
Farms	414	0.300	54.3	10.4	413	21.4
Total	521				520	
SOV	**NH_3-N**		**NO_3-N**		**TS**	
	df	MS(10^6)	df	MS	df	MS
Seasons (S)	2	3.06	2	1549.7*	2	1.70
Months (M)/S	9	1.07	8	204.9	9	1.38**
Areas (A)/M/S	24	1.05	22	189.2*	24	0.60
Groups (G)/A/M/S	72	1.24	66	98.3	72	0.62
Farms	413	1.32	361	79.4	411	0.51
Total	520		459		518	

* Error probability <0.05 or 5%, ** Error probability <0.01 or 1%.

levels of all waste water parameters than that from relatively newer and not crowded farms (KS). The levels of COD and BOD as well as EC and TS of KS farms were much lower, in some cases almost a half of NP averages. The NH_3-N and NO_3-N averages of KS farms in most cases were less than a half of the NP values. The pH values of waste water from NP farms were a little higher than that of KS farms and significant. These results could reflect the fact that due to high degree of farm crowdedness at NP and longer existence of NP dairy farms, while waste management systems were minimal, the liquid wastes which were released from dairy barns into surrounding areas contained much higher organic and inorganic substances which could eventually cause environmental pollution. Since the KS dairy farms were newer and located in a more open and expanded area, the waste water appeared to contain less amounts of organic and inorganic substances, but in the future the situation could become similar to the NP farms in a long term when dairy farming becomes more intensive but effective waste management facilities remain lacking.

B. Differences of waste water parameters due to other factors

For the data of NP farms, the analysis of variance for each parameter of the waste water was conducted using hierarchal classification with unequal subclass numbers. The results of ANOVA are presented in table 4.

1) Seasonal variation

The differences of waste-water parameters due to seasons, i.e. summer (March ~ June), rainy season (July ~ October), and dry or cool season (November ~ February), were not significant except that for NO_3-N ($p<0.05$). The differences of the parameters between months within season were highly significant for BOD and TS but non-significant for the others.

2) Variation due to areas and farm crowdedness

The differences of waste-water parameters due to three different farm areas (irrigated area, municipality area, and factory area) were non-significant except that for NO_3-N ($p<0.05$). It was noted that the 12-month average of NO_3-N in waste water from the farms in irrigated area was slightly higher than those of the other two areas (13.4 vs. 10.1, 10.5 ppm). For the differences due to the degrees of farm crowdedness, it was found that the values for COD and BOD were highly significantly different, with the very crowded farms in irrigated and municipality areas having the highest averages, and the crowded farms in factory area having the highest values. The differences of EC values due to farm crowdedness was significant, while the rest of the parameters (pH, TS, NH_3-N, NO_3-N) were not.

C. Relationship of waste-water parameters

Simple correlation coefficients between pairs of the waste-water parameters were calculated for each month of the 12-month period of study, and the correlation estimates which are consistently significant or highly significant are shown in table 5. It can be seen that some waste-water parameters were highly correlated, for example, TS with COD, BOD, and NH_3-N; and COD with BOD. These results indicated that a certain parameters can be used to predict the other in case they were highly correlated. This information can be useful when chemical analysis of any particular parameter in waste water was not possible either due to high costs or a lack of laboratory equipment. For example, EC was found to be highly correlated with TS in this study, as also reported by Menasveta (1995), which means that either one of these two parameters can be used to reflect water quality.

Table 5. Correlation coefficients of waste water parameters

Correlation coefficient	Lowest-highest estimate	Significant level and number of estimates	
		p<0.05	p<0.01
pH - EC	0.326-0.699	1	11
- NH_3-N	0.305-0.791	2	10
EC - TS	0.622-0.936	0	12
- COD	0.464-0.869	0	12
- BOD	0.402-0.784	0	12
- NH_3-N	0.382-0.904	1	11
TS - COD	0.634-0.896	0	12
- BOD	0.432-0.882	0	12
- NH_3-N	0.447-0.793	0	12
COD - BOD	0.432-0.902	0	12

D. Properties of water from wells and public waterways and farm soil

1) Well water

Some chemical and biological properties of well water which were examined in this study are shown in table 6.

In general it can be said that many quality criteria of well water used in dairy farms, which were mostly from deep wells of 20 to 50 m in depth, were close to government standards for deep-well water (pH, EC, chloride, and hardness). But some water samples were high for nitrate, total coliform, and faecal coliform, which indicated that there could be contamination due to possible seepage of liquid manure into underground water. The water samples from a shallow well were much higher in EC, chloride, nitrate, and hardness than the water from deep wells, while faecal coliform was as high as 2400 MPN/100 ml. Gould (1995) studied the contamination of nitrate to underground water in dairy farms and reported that only 47% of water samples from deep wells with more than 18-m in depth contained less than 10 mg/l of nitrate, while only 14% for water samples from deep wells of less than 18-m in depth contained nitrate less than 10 mg/l. Source of contamination was mainly from cow loafing area.

Table 6. Some parameters of well water from dairy farms

Parameter	Standards for unground water[1]	NP Farms				KS Farms	
		May	Jul.	Jan.	Ave.	Range	Ave.
pH	7.0-8.5	6.56-6.79	6.69-8.16	6.97-7.73	6.8-7.6	7.01-7.62	7.3
EC	0.0005-1 ms	0.5-6.3	0.49-5.8	0.53-6.05	0.62-6.05	1.2-1.65	1.43
Chloride	250-600 ppm	22-664	27-642	41-619	39-605	104-173	144
Nitrate	<10 ppm	0-39	0-38	0-31	0.3-36	6.7-37	21
Hardness	300-500 ppm	123-1474	91-1202	84-1267	97-1314	352-523	446
Total coliform	2.2 MPN/100 ml	0-2400	0-2400	0-2400	0-1673	0-33	16
Faecal coliform	2.2 MPN/100 ml	0-2400	0-2400	0-350	0-1656	0-33	16

[1] Sirisingh, 1982.

2) Water samples from public waterways

The water samples used in this study were collected from 4 small canals (sites) which passed by some dairy farms at NP. The values for water parameters are shown in table 7, which were average values of 12 month observations. The values for EC, TS, COD, and BOD for water sample from site (A) were distinctively higher than the other three sites because the canal at site (A) was very near to a dairy barn where liquid manure could easily contaminate the water samples. No definite seasonal trend of canal water parameters was observed during the 12-month period of study.

Table 7. Parameters of water samples from four public waterways

Parameter	Unit	Public Waterway : Sites			
		A	B	C	D
pH		6.86	6.65	6.78	7.17
EC	ms	3.01	1.30	1.49	1.26
TS	%	0.74	0.10	0.11	0.26
COD	ppm	2,872	1,129	332	4,415
BOD	ppm	1,261	198	175	542
NH_3-N	ppm	47.67	28.33	31.83	42.18
NO_3-N	ppm	3.50	5.98	3.37	4.27

3) Soil

The results from soil sample analysis are presented in table 8, they were soil samples from 16 farms at NP and 1 farm at KS, plus soil samples from virgin soils at NP and KS which were collected from land area where no cropping and no fertilizer were applied in the past. Farm soil samples from areas under long exposure to cow manure appeared to be much higher for the values of EC, K, P_2O_5, and NO_3-N, but not consistently for total N and NH_3-N, as compared with soil samples from virgin soils. The value for NO_3-N in the soil sample from NP farms were 1.5 to 35 times of the virgin soils, while those from KS farm were only 2.6 to 3.1 times.

Table 8. Chemical analysis of soil samples from dairy farms

Parameter	NP virgin soil		NP(16 farms)			
	1	2	May	Aug.	Jan.	Ave.
pH	6.81	7.53	6.47-8.29	6.45-7.56	6.89-8.24	6.70-7.88
EC	0.05	0.54	0.30-1.85	0.23-1.50	0.23-1.20	0.31-1.45
K	100.4	90.1	1244-3851	387-3264	914-2884	848-3176
P_2O_5	7.90	7.88	7.1-169.3	26.5-369.1	6.5-194.7	14.4-224.3
Total N	0.06	0.09	0.003-0.064	0.006-0.670	0.084-0.300	0.046-0.120
NH_3-N	1.05	0.52	0.10-1.22	0-1.75	0.52-1.40	0.44-0.96
NO_3-N	0.91	0.84	3.36-31.92	1.40-13.16	1.40-8.57	3.10-13.77
Parameter	KS (N=1 farm)					
	Virgin soil	May	Aug.	Mar.		Ave.
pH	7.58	8.55	8.22	8.00		8.26
EC	0.52	0.35	0.49	2.80		1.21
K	315.0	1904.9	1804.0	1604.5		1771.1
P_2O_5	13.75	13.49	56.31	97.94		55.91
Total N	0.15	0.02	0.02	0.09		0.04
NH_3-N	0.98	1.22	0.35	0.28		0.62
NO_3-N	1.75	5.35	4.55	6.16		5.37

Note : Units of measurement being EC (ms), K (mg/kg), P_2O_5 (mg/100g), Total N (g/100 g), NH_3-N (mg/100g), NO_3-N (mg/100g).

The lower values for total N in many farm soil samples comparing with virgin soil could indicate more leaching and conversion of N in farm soils. The values for K for both NP and KS farm soils were 8-30 times larger than that of virgin soil. Obviously these soil components such as NO_3-N could leach from top soil to underground level if exposed to manure for a long period of time and may eventually contaminate underground water.

CONCLUSION

The results from this investigation clearly showed the need for implementing appropriate waste management systems for smallholder dairy farms in Thailand and in other developing countries. Although each farm may have only small numbers of dairy animals, in this case approximately 20 animals, but when a large number of farms existed in small area the bulk of animal wastes produced each day can create long-term environmental problems for farmers themselves as well as for other people in neighboring areas. Liquid wastes from dairy farms could contaminate water resources and public waterways. Piling and drying of manure on bare land surface could result in leaching and seeping of inorganic and organic matters to underground water. It is recommended that low-cost cement floor for drying manure should be constructed on smallholder dairy farms, including cement drainage ditches for waste water and liquid manure disposal and sewage tanks for holding of liquid waste outside dairy barn. These low-cost facilities should be viewed as a short-term solution and should help prevent much pollution from dairy farms. Other long-term investment such as central water treatment systems or biogas gas digester can be useful but requires careful planning with active farmer participation in decision-making process.

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