# Bacteriological and chemical (nitrogen, phosphorus) characterization of liquid wastes discharged by four dairy farms (Vendée, France).

*Caractérisation bactériologique et chimique (azote, phosphore) des effluents émis par quatre élevages laitiers (Vendée, France).*

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## Abstract

*Experimental device were set up on four dairy farms of a 23 km² watershed. Three farmsteads, including livestock buildings and characterized by different cattle numbers and levels of equipment, were hydrologically isolated to concentrate all liquide wastes flowing out to surface water at one single outlet. Grab and average effluent samples were collected through two winters (1995 and 1997). Fecal coliforms (FC) concentrations were close to 105-106 FC/100 ml. Those concentrations are similar from one farm to other, and do not depend on cattle numbers. Nitrogen losses (50% ammonia) reached 10 kg N/Livestock Unit (L.U.) between november and apris of the most rainy winter. Total phosphorus losses reached 4 kg P/L.U. (60% phosphates).*

*Keywords : livestock housing, cattle effluents, fecal coliforms, phosphorus.*

## Résumé

Des dispositifs de mesure expérimentaux ont été mis en place sur quatre élevages laitiers d'un bassin versant de 23 km². Trois exploitations, regroupant l'ensemble des bâtiments et différentes par leur cheptel et leur niveau d'équipement, ont été isolées hydrologiquement de façon à collecter l'ensemble des effluents émis dans le milieu en un seul exutoire. Des échantillons fractionnés et moyens ont été prélevés au cours de deux campagnes hivernales, en 1995 et 1997. Les concentrations en coliformes fécaux (CF) sont proches de 105-106 CF/100 ml. Elles sont comparables d'une exploitation à l'autre, et ne dépendent pas de la taille du cheptel. Les pertes en azote, pour moitié sous forme ammoniacale, ont atteint 10 kg N/UGB entre novembre et avril de l'hiver le plus pluvieux. Les flux de phosphore ont atteint 4 kg P/UGB, dont 60% sous forme de phosphates.

Mots-clés : bâtiments d'élevage, effluents bovins, coliformes fécaux, phosphore.

## 1. Introduction

Agricultural delivery of nitrogen and phosphorus to surface water is usually considered as coming from non-point sources. As a matter of fact, research focuses on diffuse pollution caused by fertilizers at different study scales, from experimental plots to watersheds (Heathwaite *et al*., 1996). Concerning bacteriological contamination, different experimental studies and models are developped to quantify run-off contamination after unsafe slurry applications (Bouedo *et al*., 1991 ; Moore, 1989).

On the other hand, little work has been done on agricultural point sources pollution due to livestock (Parráková and Fratic, 1980, Anonymous, 1992a -b, 1995). Two main sources are however responsible for surface water bacteriological contamination by livestock. First, animal manure is a source of pathogens and nutrients as animals water straight in rivers and ponds (Hunter and Mc Donald, 1990). Solutions exist, such as fencing livestock from streams and providing off-stream watering areas (Godwin and Miner, 1996). Second, stock farms impacts can be quite important as livestock housing do not conform to a few basic advocations, such as having sufficient storage facilities. A highly concentrated effluent can flow out of the farmstead within the winter stalling period (four to six months). A recent investigation hold in France shows that this situation is not uncommon at all. Freysse and Michaud (1997) pointed out that liquid manure and wastewaters are not stored for 50% per cent of the cattle. Moreover, 19% cattle buildings set up at less than 35 meters from a waterway. At least, livestock operations seem to be responsible for different diseases outbreacks, which is quite worrying for both human and animal health (Pell, 1997).

In order to study the real impact of animal houses on water quality and to compare it with non point sources pollution, an experimental study was carried out on a Vendée small watershed (France). This paper deals with the main results collected straight downstream of four dairy farms.

## 2. Study area

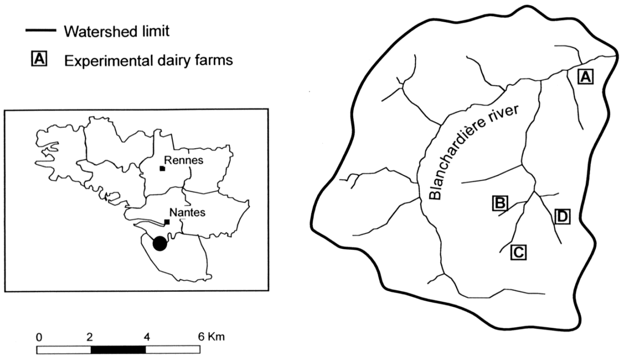


*Figure 1.*
*Location of the Blanchardière catchment area in relation to Western France ;*

Figure 1 shows location of the Blanchardière watershed (23km²) in relation to Western France. Most of the 18 cattle farms of the area are mixed crop-livestock farms, rearing dairy cows and bull calves. A specific inquiry in 1994 pointed out an average lack of liquid manure storage tank of 620 $m^3$ per cattle farm. However, few cattle breeders whose livestock exceed the limit of 70 Livestock Units (L.U.) have to comply with the Programme of Control of Pollution from Agricultural Origin (PCPAO). As part of this programme, they have to improve their livestock housing and manure storage facilities to put an end to wastewater discharges.

Table 1 compares the 4 experimental farms main breeding characteristics, considered as representative of all the farms of the area. The four dairy farms (A, B, C, D) are set up within the 200 meters area lining the nearest waterway. A, B and C show important storage capacity shortage, whereas dairy farm D carried out important improvements as part of the PCPAO.

| | Experimental dairy farms | | | |
|---|---|---|---|---|
| | A | B | C | D |
| FARM LIVESTOCK<br>Cattle number (L.U.)<br>Dairy cows number | <br>63<br>38 | <br>112<br>50 | <br>109<br>50 | <br>120<br>57 |
| STOCK RAISING PRACTICES | | | | |
| Animal buildings | free-stall housing | | | |
| Dairy cows exercise area roofing | no roof | | roofed | |
| Stalling period | half-november to half april (4 to 6 months) | | | |
| Loose straw on bedding area<br>(kg.straw.week$^{-1}$.L.U.$^{-1}$)<br>Liquid manure storage lack ($m^3$)<br>Solid manure storage lack ($m^2$) | 15<br><br>1.373<br>0 | 20<br><br>425<br>242 | 30<br><br>634<br>45 | 18.5<br><br>0<br>0 |

*Table 1*
*Characteristics of the four experimental livestock farms (A, B, C, D)*

## 3. Methods

### 3.1. Measuring equipment

The four farmsteads were fenced by a ditch collecting the whole effluent flowing out. One single outlet gathered the main effluents in a two meters long concrete channel :

- liquid manure streaming from animal houses and manure storage facilities whose walls and bottom were not tight,
- milking parlour wastewater,
- storm water trickling over dirty concrete areas and bunker silos.

Figure 2 represents farm buildings and storage facilities of dairy farm B as an example of an experimental site.

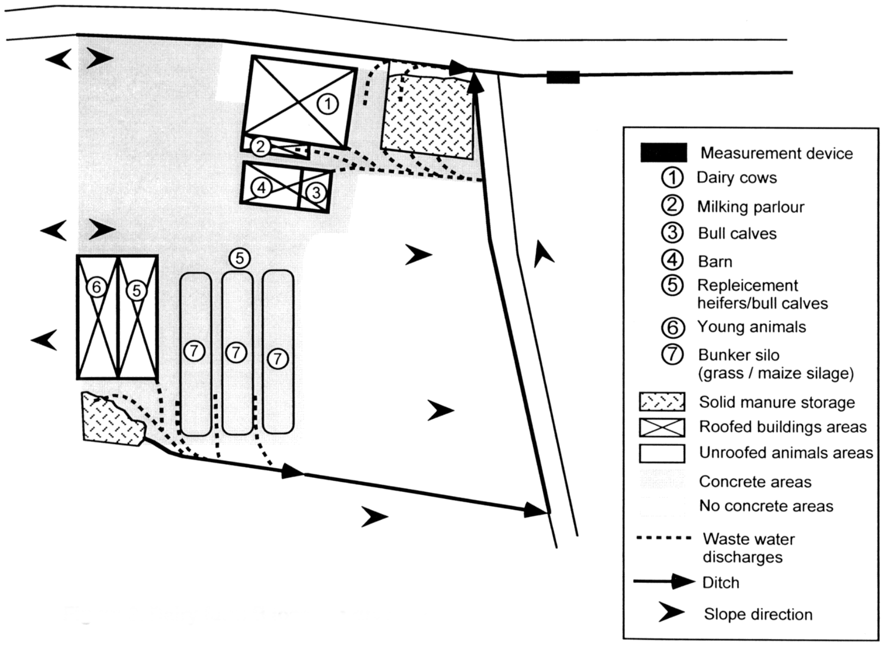


*Figure 2.*
*Location drawing of dairy farm B.*

A measuring and collecting equipment was installed straight downstream the artificial outlet. Data loggers SAB600 HDL recorded wastewater level in the channel every 6 minutes. Automatic samplers ISCO 3700 connected to data loggers collected samples in the concrete channel. A rain gauge connected to the data logger measured rainfall every 6 minutes. As data loggers were equiped with modem, samplers were easily remote activated according to rains.

### 3.2. Sampling programme

The sampling programme combined two series of average samples.

- a series of average samples was planned during storm events, to evaluate flood concentrations. Hydrograph events were studied through flow-slaved samples, so that sample collection frequency increased in proportion to waterflow.
- a series of time-slaved samples described wastewater average baseflow concentrations continuously produced by the dairy farms.

### 3.3. Analytical methods

Effluent samples were kept cold (4°C) and dark to the Veterinary Analysis Laboratory of Vendée. They were analyzed for orthophosphates ($P\text{-}PO_4$), total phosphorus (TP), ammonium ($NH_4$) and total Kjeldahl nitrogen (N-TKN).

Orthophosphates are coupled with ammonia molybdate and reduced by acorbic acid to form a coloured compound measured at 800 nm. Total phosphorus is measured at the same wavelength after mineralization with sulfuric acid. (Rodier, 1996, AFNOR NF T 90-023). Ammonium ($NH_4$) was measured colorimetrically at 630 nm (Rodier, 1996, AFNOR NF T 90-015). Organic nitrogen was converted to ammonium by sulfuric acid mineralization and next determined by substracting ammonium from total Kjeldahl nitrogen (Rodier, 1996, AFNOR NF T 90-110).

Bacteriological samples were collected in sterilized 250 ml polyethylen stoppered flasks and put to culture within 8 hours after collecting. Fecal coliforms (FC) were selected as fecal indicators, and a Membrane Filtration technique used for coliforms enumerations. Membranes are first incubated 24 hours at 44°C on Triphenyltetrazolium and Tergitol media, fecal coliforms are next confirmed at the same temperature on a Lactose medium (Rodier, 1996, AFNOR NF T 90-414).

## 4. Results and discussion

### 4.1. Dairy farms A, B, C within november 1994 to april 1995.

Table 3 shows main results concerning baseflow and flood chemical elements concentrations.

Baseflow concentrations were very high and varied over a wide range of values. N-TKN and $N\text{-}NH_4$ concentrations were particularly high for all samples (263.3-798 mg $N.l^{-1}$ for N-TKN, 224-612.7 mg $NH_4.l^{-1}$), followed by orthophosphates and total phosphorus. Farm C samples were at least twice more concentrated than farms A and B samples. On these latter whose animals exercise areas had no roof, effluents were slightly more dilute by urine and wastewater between two rainfalls.

Flood concentrations varied over a narrow range of values (11.9-25.4 mg P. $l^{1}$ , 45.1-110.7 mg N. $l^{-1}$). The higher concentrations were observed on farm A, and no longer on farm C. Dairy farm C was particularly poorly equiped with liquid manure storage facilities within the study period. Rainfall played here an essential role by massively displacing liquid manure badly stored in a no-tight storage tank. The amount of ammonia in total Kjeldahl nitrogen was almost constant from one farm to another, and close to 53.6% (± 9.4). The amount of orthophosphates in total phosphorus was close to 61.2% (± 5.7) in all samples.

For all samples, outflows between two storm events were highly more concentrated than samples collected during a significant storm event (rainfall > 5mm). The baseflow / flood concentrations ratio varied from 2.1 to 3.7 for the different phosphorus forms on A and B, to 8.6 and 8.8 for dairy farm C.

The nitrogen baseflow / flood ratios varied as phosphorus but were twice higher for TKN and $N\text{-}NH_4$ (from 4.4 to 9.2 on farms A and B, and 11.6 and 16.3 on farm C), which could suggest that nitrogenous compounds were leached more easily than phosphorus compounds, specially during baseflow periods.

| | | dairy farms | | |
|---|---|---|---|---|
| | | A | B | C |
| baseflow mean concentrations | TP (mg P/l) | 53.0 | 44.9 | 107.2 |
| | $P\text{-}PO_4$ (mg $PO_4$/l) | 112.5 | 79.2 | 209.6 |
| | N-TKN (mg N/l) | 490.0 | 263.3 | 798.0 |
| | $N\text{-}NH_4$ (mg $NH_4$/l) | 387.0 | 224.0 | 612.7 |
| flood mean concentrations | TP (mg P/l) | 25.4 | 11.9 | 12.5 |
| | $P\text{-}PO_4$ (mg $PO_4$/l) | 43.1 | 23.1 | 23.8 |
| | N-TKN (mg N/l) | 110.7 | 45.1 | 68.4 |
| | $N\text{-}NH_4$ (mg $NH_4$/l) | 73.5 | 24.2 | 37.5 |

*Table 3.*
*Total phosphorus (TP), orthophosphates ($P\text{-}PO_4$), total Kjeldahl nitrogen (N-TKN), ammonium ($N\text{-}NH_4$) mean concentrations of baseflow samples (n=5) and flood samples (n=10) collected on farms A, B, C, within november 1994 to april 1995*

Continuous flow recorded permitted to estimate both baseflow and flood volumes, and by the way, to estimate nitrogen and phosphorus losses (Table 4). Within a 181 days study period characterized by a 520 mm cumulated rainfall, the most important losses were observed on the smallest farm (63 L.U.) where they reached 208.7 g N. $L.U.^{-1}$ $day^{-1}$. Baseflow losses represented about a third of the 3 farms total export.

The comparison of the 3 farms pointed out main explanatory factors such as insufficient liquid manure storage capacity, or husbandry practices. Insufficient quantity of straw on bedding area and insufficient cleaning of the exercise and alimentation areas generated a semi-liquid manure, which was more easily removed from the solid manure storage facility. Farm C which had a bigger liquid storage shortage than farm B, showed smaller losses thanks to roofed animals areas and to the greater amount of straw used by the breeder to get a high dry matter farmyard manure.

| | dairy farms | | |
|---|---|---|---|
| | A | B | C |
| TP (g P.$L.U.^{-1}$. $day^{-1}$) | 77.2 | 34.4 | 22.5 |
| TKN (g N. $L.U.^{-1}$. $day^{-1}$) | 208.7 | 72.1 | 91.7 |

*Table 4.*
*Total phosphorus (TP) and total Kjeldahl nitrogen (TKN) losses within 181 days (november 1994 to april 1995)*

Concerning fecal coliforms, table 5 presents steady geometric means from one farm to another. Minima and maxima confirmed that the concentrations varied over a narrow range of values, (4.3-6.4 log10 fecal coliforms per 100 ml). No significative difference was found between the 3 farms, neither on baseflow concentrations, nor on flood conditions.

| | | dairy farms | | |
|---|---|---|---|---|
| | | A | B | C |
| baseflow concentrations | mean | 5.50 | 5.53 | 5.49 |
| ($log_{10}$ fecal coliforms / 100ml) | minimum | 5.18 | 5.09 | 5.04 |
| | maximum | 5.96 | 5.89 | 5.98 |
| flood concentrations | mean | 5.88 | 5.32 | 5.39 |
| ($log_{10}$ fecal coliforms / 100ml) | minimum | 5.46 | 5.03 | 4.30 |
| | maximum | 6.40 | 5.78 | 5.90 |

*Table 5.*
*Fecal coliforms bacteria concentrations of background samples (n=5) and flood samples (n=10) collected on farms A, B, C, within november 1994 to april 1995*

### 4.2. Comparison of farm B with a well equiped dairy farm within november 1996 to april 1997

As part of the PCPOA, dairy farm D carried out important improvements during summer 1996. Animals areas were roofed, solide manure storage facilities were made waterproof and all wastewater collected to a new 1,000 $m^3$ drained tank. Dairy farm D was compared with dairy farm B which was the most similar farm of the area considering livestock and animal housing (table 1). Means concentrations are presented in table 6.

Concentrations measured on dairy farm B within november 1996 to april 1997 were comparable with concentrations obtained within november 1994 to april 1995 (table 3).

As soon as improvements were achieved on dairy farm D, baseflow concentrations did not exceed 14.9 mg $N.l^{-1}$ and 3.48 mg $P. l^{-1}$ . These mean concentrations were twenty times as concentrated as B for total phosphorus, and sixty times as concentrated for total Kjeldahl nitrogen.

Dairy farm D flood mean concentrations appeared to be twice smaller than baseflow concentrations for main parameters, but no significative difference was found. Dairy farm B flood mean concentrations reached 50.4 mg $N.l^{-1}$ and 14.4 mg $P. l^{-1}$. Even with rain dilution, these concentrations remained ten times as high as dairy farm D.

| | | B (non improved) | D (improved) |
|---|---|---|---|
| baseflow mean concentrations | TP (mg P/l) | 43,2 | 1,8 |
| | P-PO$_4$ (mg PO$_4$/l) | 88,3 | 2,0 |
| | N-TKN (mg N/l) | 348,5 | 9,1 |
| | N-NH$_4$ (mg NH$_4$/l) | 304,6 | 5,0 |
| flood mean concentrations | TP (mg P/l) | 14,4 | 1,1 |
| | P-PO$_4$ (mg PO$_4$/l) | 29,6 | 1,2 |
| | N-TKN (mg N/l) | 50,4 | 4,4 |
| | N-NH$_4$ (mg NH$_4$/l) | 30,7 | 2,7 |

*Table 6.*
*Total phosphorus (TP), orthophosphates (P-PO$_4$), total Kjeldahl nitrogen (N-TKN), ammonium (N-NH$_4$) mean concentrations of baseflow samples (n=12) and flood samples (n=7) collected on farms B et D within november 1996 to april 1997*

Fecal coliforms enumerations on dairy farm B in 1996-97 confirmed both baseflow and flood concentrations in 1994-95, with a baseflow mean concentration of 5.78 $\log_{10}$ fecal coliforms / 100ml (4.96-6.79 $\log_{10}$ fecal coliforms / 100ml) and a flood mean concentration of 5.29 $\log_{10}$ fecal coliforms / 100ml (4.78-5.9 $\log_{10}$ fecal coliforms / 100ml).

Fecal coliforms enumerations at dairy farm D outlet showed wide variations. At the beginning of the study period, all facilities improvements were not achieved. Peacks occurred on former samples, as wastewater was not collected and channeled to the tank (5.99 $\log_{10}$ fecal coliforms / 100ml). Once improvements were achieved, the enumerations revealed less than 30 FC / 100 ml, except for one sample (4.32 $\log_{10}$ fecal coliforms / 100ml ) collected as the breeder was cleaning a spreader and sent wastewater to the ditch and not to the tank.

## 5. Acknowledgments

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