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Evaluation of environmental adjustment contract for pig production in Pinhal river sub-basin

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ABSTRACT

The objective of this study was to evaluate the efficiency of Environmental Adjustment Contract for pig production (EAC) in improving the water quality in Pinhal River sub-basin, located in Concordia, west part of Santa Catarina State. The monitoring of water parameters occurred in eight sites of the river, during three years (2006-2009). To assess whether the EAC was efficient, Brazilian Water Law was used. The average annual concentrations of Total Dissolved Solids (TDS) were: 130.2 mg/L, 137.0 mg/L, and 99.8 mg/L. Turbidity showed the same trend of TDS. Concentrations of nitrate and Total Phosphorus (TP) decreased from 2006 to 2009; nitrate from 1.81 mg/L NO_3-N to 1.54 mg NO_3-N; TP from 0.29 mg/L to 0.10 mg/L, respectively. The same trends occurred for Fecal Coliforms and *E. coli*. These results show that obligations proposed by EAC had potentially improved water quality. These results can help the government, farmers, and society to establish environmentally sound and sustainable programs for pig production.

Keywords: manure; nutrients; riparian zone; water quality.

Avaliação do termo de ajustamento de conduta da suinocultura na microbacias do rio Pinhal

RESUMO

O objetivo deste estudo foi avaliar a eficiência do Termo de Ajustamento de Conduta (TAC) da suinocultura na melhoria da qualidade da água na sub-bacia do Rio Pinhal, localizada em Concórdia, Oeste de Santa Catarina. O monitoramento dos parâmetros de qualidade da água ocorreu em oito pontos entre os anos de 2006 a 2009. Para avaliar se o TAC foi eficiente, utilizou-se como referência a lei brasileira de classificação das águas. As concentrações anuais médias de Sólidos Totais Dissolvidos (STD) foram: 130,2 mg/L, 137,0 mg/L e 99,8 mg/L. A Turbidez mostrou a mesma tendência das concentrações de STD. As concentrações de nitrato e fósforo total (PT) reduziram de 2006 a 2009; nitrato de 1,81 mg/L NO_3-N para 1,54 mg/L NO_3-N; PT de 0,29 mg/L para 0,10 mg/L, respectivamente. As mesmas tendências foram verificadas para coliformes fecais e E. coli. Os resultados demonstram que o EAC proporcionou melhorias na qualidade da água. Os resultados poderão ajudar governos, agricultores e sociedade para estabelecer programas sustentáveis para a produção de suínos.

Palavras-chave: dejetos; mata ciliar; nutrientes, qualidade da água.

1. INTRODUCTION

Brazil is one of the greatest animal producer in the world and studies from various international organizations concluded that in the next ten years the country will be the greatest producer (FAO, 2006; OECD, 2004). A set of characteristics promoting this condition would include among others are as follows: (1) natural resources in abundance, mainly water and soil; (2) national market in ascension; (3) workers; and (4) low cost of production. This position could be good to society and to the economy of the country, but things must be done properly to avoid harming environment.

Hooda et al. (2000) reported that potential pollution arising from agricultural activities may increase because of food production system intensification. The demand for food production is generally met by a combination of high yielding varieties with greater reliance to fertilizers and on imported animal feed in livestock husbandry areas. Ouyang et al. (2006) claimed that pollution of surface water with toxic chemicals and eutrophication of rivers and lakes with excess nutrients are of great environmental concern worldwide. Agricultural, industrial, and urban activities are considered as major sources of chemicals and nutrients in aquatic ecosystems, while atmospheric deposition could be an important source to certain constituents such as mercury and nitrogen.

To promote profitable production without harming the environment, one of the first things to do is to legalize farming operations. Brazil has lots of environmental legislations that control agriculture, livestock, water, soil, and forest, but few farms have environmental licenses or permits to operate.

In 2004, a social process guided by Environmental State Court had the objective to legalize pig farms in the region of Alto Uruguai Catarinense. This involved 2,000 pig farmers that have the opportunity to sign an Adjustment Environmental Contract (EAC). This Contract gave the farmers a period of three years to implement and make all corrections to take the environmental license. The two main objectives of EAC were: (1) improve rivers water quality; and (2) maintain farmers' productivity and sustainability. Because of social and market pressures, the middle-west and western regions of Santa Catarina State started to implement it because they had the highest animal density in the country. Stakeholders didn't have practical knowledge about this kind of process and generated results and indicators to evaluate it, because society asked them about the efficiency of EAC.

Revenga et al. (2005) analyzed the effects of various human influences on freshwater rivers and streams due to large variability of both natural and anthropogenic disturbances within most lotic aquatic systems. Human activity has had profound effects on rivers and streams world-wide (Ward and Trimble, 2004), with many freshwater systems being impacted by multiple physical (e.g. channel straightening), chemical (contamination by organic and inorganic pollutants) and biological (e.g. introduction of invasive species). A long-term time series of similar data throughout a watershed could allow preventive action to be taken if increases in animal waste impacts are detected, or could allow confirmation of reductions in export through improvement in waste management (Karr et al., 2003).

The aim of this study was to evaluate the effect of implementing Adjustment Environmental Contract for pig farms on water quality of Pinhal sub-basin.

2. MATERIALS AND METHODS

Santa Catarina has a legislation to issue an environmental license to Concentrated Animal Feeding Operations (CAFO). In 2001, Embrapa Swine and Poultry Research Center staff and scientists made a diagnosis in Alto Uruguai region about the number of pig farms that had this license. The conclusion was that 95% of farms didn't have the license. Because of it, the

Environmental State Court established a volunteer Adjustment Environmental Contract (EAC) to pig farms. EAC started in 2004.

This sub-basin was chosen because 80% of pig farmers have signed EAC. The study area is consisted of a 1,345.3 ha sub-basin at the upper Pinhal River catchment. Pinhal River is located in Concordia, Santa Catarina, Brazil. The highest points of nearby hills reach elevations of 724 m, while the lowest parts are at about 574 m above sea-level.

Pinhal is a first-order stream and later form a second-order stream with Guilherme River and a third-order stream with Rancho Grande River that drains into the Uruguay River. Uruguay basin has a fundamental importance because it is a trans-boundary basin; it has an extension of 2,200 km. Argentina, Bolivia, Brazil, Paraguay and Uruguay share the basin. In Brazil, Uruguay divides the states of Santa Catarina and Rio Grande do Sul. Pinhal sub-basin is located near the urban region of Concordia. It has farms, villages, school, cemetery, and small industry that produces and processes tea leaves. There is also the industrial district of the city. One of these industries produces blood and bone meals from animal carcasses and theirs effluents after treatment with bioreactors, are being discharged to Pinhal River.

Fields or parts of fields from 17 livestock farms were in the sub-basin. Detailed farm management data were collected during 2006, 2007, and 2008 with structured interviews in each farms. We recorded specific management practices including total farm area, fertilizer and manure application, crop yields for each of the fields, animal production, environmental technologies to manage wastes, and level of farm education. Pinhal sub-basin has pigs, poultry, and dairy cows (Table 1). The use of livestock slurry as fertilizer is widespread. Pigs slurries are typically stored in open or closed ditches, generally close to the stables and/or Pinhal River.

Table 1. Number of animal unit per farm during years 2006, 2007, and 2008.

Farm	**Swine**			**Broiler**			**Dairy**		
	2007	**2008**	**2009**	**2007**	**2008**	**2009**	**2007**	**2008**	**2009**
1	-	-	-	-	73	-	-	27	-
2	-	-	253	-	-	88	-	-	22
3	-	-	-	-	-	-	-	120	-
4	-	80	80	-	-	-	-	19	22
5	213	213	213	-	-	-	17	54	59
6	97	97	97	-	-	-	16	22	16
7	168	171	168	-	-	-	24	51	42
8	133	133	147	-	-	-	-	-	-
9	-	117	-	-	-	-	-	27	-
10	880	907	533	-	-	-	12	35	13
11	-	-	-	-	-	-	-	-	18
12	-	-	67	-	-	-	-	-	19
13	-	-	-	-	-	-	-	-	9
14	73	60	61	70	71		21	35	45
15	117	117	319	-	-	-	14	27	14
16	-	-	213	-	-	-	-	-	25
17	-	214	-	-	150	-	-	34	-
Total	1,683	2,110	2,154	70	295	88	104	449	305

*Animal Unit (AU) is equivalent to an animal with 450 kg live weight.

Eight monitoring sites that represent different areas were selected. The different sampling sites were characterized by the occupation of animal farms in their surroundings. In this way, we can infer about the influence of different animal operations on water quality at the sub-basin level.

Fortnightly, water quality monitoring was carried out at eight sites from August 2006 to August 2008 and thereafter, at monthly intervals until April 2009. Approximately, 2 L of stream water was collected on the same day at each site. If possible, water samples were always taken in the middle of the stream, 20 cm bellow water surface. The sites were located at places were conditions were most representative and homogeneous, away from areas with point sources, mixing zones, and non-point sources. The description of each site is presented in Table 2.

Table 2. The location and land use structure of the monitoring sites.

Land Use Site	Location		Area (ha)	Altitude (m)	Land Use Description
	N	E			
1	69^0 90' 67''	40^0 73' 80''	23.3	724	one of the principal tributaries of the Pinhal River, lots of spring contribute to this tributary, there isn't riparian buffer, soil with erosion, animal manures go direct to the river
2	69^0 89' 98''	40^0 63' 68''	67.2	705	another principal tributary of the Pinhal River, there aren't any economy activity, forest is preserved and in agreement with the environmental brazilian law
3	69^0 89' 27''	40^0 71' 44''	209.6	636	upright of this there are farms with pigs, poultry and dairy, the agricultural area is occupied with corn, pastures, and grasslands, and in these areas organic and inorganic fertilizers are used, the riparian buffer is not totally preserved
4	69^0 89' 22''	40^0 71' 56''	197.6	630	mixing zone of tributaries from Sites 1 and 3 and from Site 2
5	69^0 87' 87''	40^0 82' 64''	411.6	629	pig farm beside the river and the tank of waste is 7 m from the river, riparian buffer in a strip of 10 m, but only from one side of the river, upright of this Site there is a little village and farms with pigs, poultry and dairy, riparian buffer is reduced in both sides along the river, lands with corn and pastures
6	69^0 87' 44''	40^0 88' 57''	112.0	619	upright farms with pigs, poultry and dairy, riparian buffer is reduced in both sides of the river, it receives the effluents of a fish farming integrated with pigs, lands with corn and pastures
7	69^0 86' 95''	40^0 92' 62''	150.2	607	downstream from the center of the village, where there is a school, and cemetery, also suffers influences of agricultural activities and livestock, buffer zone more present than in the other Sites
8	69^0 85' 91''	40^0 93' 98''	173.7	574	pigs and dairies farms around, land with a rise slope and with cultivation of corn, natural and cultivated pasture and pines, good condition of the riparian buffer in some margins of the river

Water samples were analyzed in-situ with a Multiprobe Hydrolab (Hanna, mod. HI929828) for temperature (^{0}C), pH, electrical conductivity (EC, µS/cm), and dissolved oxygen (DO, mg/L). Water samples were collected and analyzed for turbidity (NTU), Total Dissolved Solids (TDS, mg/L), Chemical Oxygen Demand (COD, mg/L), nitrate-nitrogen (NO_3-N, mg/L), and nitrite-nitrogen (NO_2-N, mg/L). Standard protocols for sampling, sample stabilization and analysis were adopted for all water quality variables following the Standard

Procedures for Water Analysis published by the American Public Health Association (1992). Nitrate-nitrogen was determined spectrophotometrically with flow injection (FIALab 2500) using the modified Griess reaction. For the determination of NO_3-N, the nitrate is being reduced to nitrite by a cadmium-copper column.

Water samples to Fecal Coliforms and Escherichia coli were analyzed by Petrifilm plates and in strict accordance with the guidelines APHA (1992). Salmonella was isolated from running water by immersion of a sterile pad in the water for 48 h and the presence (+) or absence (−) of Salmonella was analyzed following the procedures described by Quinn et al. (1994).

Rainfall is season-dependent in the area. Rainfall was measured in Embrapa Swine and Poultry Climatological Station. It is located 20 km from the sub-basin.

There is no gauging on the stream, but flow was estimated with float methodology (Palhares et al., 2007). Pinhal River is shallow, with average depth of <1.5 m. Flows in the river were mostly variable during seasons, as they are affected by rainfall.

The normal factor to be compared were the eight sample Sites. These Sites were evaluated longitudinally over 3 years thus we decided to create one factor to be combined with these Sites, 8 Sites x 3 years. Year 1 was August 2006 to July 2007; Year 2 was August 2007 to July 2008; Year 3 was August 2008 to April 2009. To compare the levels of 2 and 2 factors and their interactions, we realized a variance analysis (F Test) for a factorial model of two-factor. Means were compared by Student T Test and significance by the F Test at 5% probability. We use SAS version 9.1 XP-PRO-SAS (2002).

3. RESULTS AND DISCUSSION

3.1. Site-Productivity Characteristics

In 2006, 17% of farmers did soil analysis. In 2007 and 2008, this percentage was 50% and 38%, respectively. All farmers used the same formula (9-33-12) of chemical fertilizer during those three years. Farmers consumed about 332 bags of chemical fertilizer in 2006, 867 bags in 2007 and 508 bags in 2008. Urea (45-0-0) was also used by all farmers for topdressing their maize crops and consumed 332, 707 and 1,489 bags in 2006, 2007 and 2008, respectively. Table 3, shows chemical nitrogen, phosphorus and potassium used per hectare. All producers have also applied pig, broiler, and/or dairy manures as fertilizer on their crops and pastures, but the actual amount applied was not documented properly. Differences between nutrients used per year were related to economical factors and farmer`s decisions.

Table 3. Chemical fertilizers used in Pinhal sub-basin by year.

Nutrients	Nutrients (kg)			N as Urea (kg)			Nutrients used (kg/ha)			N as Urea used (kg/ha)		
	2006	2007	2008	2006	2007	2008	2006	2007	2008	2006	2007	2008
Nitrogen	1,494	3,902	2,286	3,735	7,953	16,751	18	13	8	57	41	91
Phosphorus	5,478	14,306	8,382	-	-	-	66	46	28	-	-	-
Potassium	1,992	5,202	3,048	-	-	-	24	17	10	-	-	-

Sites located in the region from the middle to the end of the sub-basin had the highest animals' populations. Site 6 had the highest stocking density in all years (mean of 8.31

AU/ha) while Site 8 had the second highest stocking density of 2.71 AU/ha (Table 4). The higher stocking density on Site 6 was due the presence of the largest pig farm in this region.

Table 4. Number of animal units and stocking density in each monitoring site.

Monitoring Site	Animal Unit			Stocking Density (AU/ha)		
	2007	**2008**	**2009**	**2007**	**2008**	**2009**
1	-	120	-	0,00	5,15	0,00
2	0	0	0	0,00	0,00	0,00
3	165	243	304	0,79	1,16	1,45
4	165	243	304	0,84	1,23	1,54
5	131	244	936	0,32	0,59	2,27
6	1,025	1,075	693	9,15	9,60	6,19
7	114	661	114	0,76	4,40	0,76
8	422	488	500	2,43	2,81	2,88

*****Animal Unit (AU) is equivalent to an animal with 450 kg live weight.

Site 1 is located in the upper part of the sub-basin. It is the only site where there were dairies with full access to the springs and river. The point of water sampling was located in the lowest part of the farm to evaluate the impact of animals on water quality. The farm also lack storage and wastewater treatment systems. Effluents trickled through the soil could even reached the river, depending on weather conditions.

Site 2 has no animal units because it was a region of protected area. In this region, environmental legislations related to conservation of forests and waters were fully met. This site therefore should be considered as an area where there is low human intervention. Possible sources of pollution could be wildlife and septic tanks.

The data show the high spatial animal concentration that existed in the sub-basin. This concentration can be explained by the characteristics of relief. Mainly, between Sites 6 and 7, relief is smoother, showing areas with low slope, with facilitates for pigs and broilers and agricultural use of land. Therefore, this region is more susceptible to receive larger amounts of chemical and organic fertilizers. The hilly regions are used by dairy farmers, where building large animal facilities and cultivating grain crops were prohibitive.

3.2. Environmental Characteristics and Water Quality

Total precipitation in 2006 (1,425 mm) was 78% of the long-term average value (1,825 mm), indicating a drier year. In 2007, total precipitation (2,108 mm) was 115% of the long-term average, indicating a wetter than normal year. In 2008, total precipitation was (1,855 mm), indicating a normal year (Table 5). Considering the monitoring year, total rainfall in Year 1 (August 2006 to July 2007) was 2,173 mm; Year 2 (August 2007 to July 2008) was 1,707 mm; Year 3 (August 2008 to April 2009) was 1,273 mm.

Autumn and winter are the driest seasons while March is the driest month. The rainfall probability is high in the spring. Strongest rains occurred in September and October. In August and September there is the soil preparation period for corn crops when farmers use a lot of pig manure as fertilizer, giving more importance to the kind of soil tillage and soil management system.

Table 5. Monthly rainfall totals during the full monitoring period, with annual rainfall totals (August 2006–March 2009), long-term (1987–2005) monthly annual rainfall means, minimum, and maximum in parenthesis.

	2006		2007		2008		2009		Long-Term
Month	**mm**	**%**	**mm**	**%**	**mm**	**%**	**mm**	**%**	**Mean**
1	-	-	196	107	130	71	150	82	183 (79-326)
2	-	-	204	132	177	114	147	95	155 (29-477)
3	-	-	167	152	81	74	58	53	110 (29-227)
4	-	-	264	198	235	176	-	-	133 (19-251)
5	-	-	286	193	71	48	-	-	148 (22-409)
6	-	-	62	44	265	187	-	-	142 (45-278)
7	-	-	219	169	38	29	-	-	130 (60-246)
8	149	123	56	46	110	91	-	-	121 (6-312)
9	132	75	123	70	194	111	-	-	175 (35-399)
10	83	38	205	94	374	172	-	-	218 (83-533)
11	271	195	205	148	124	89	-	-	139 (24-293)
12	170	121	121	86	56	40	-	-	140 (46-416)
Total	805		2,108		1,855		355		
Maximum	271		286		374		150		
Minimum	83		56		38		58		

* % of monthly rainfall considering long-term mean.

The river flows were measured in Sites 4 and 5 only because these places had the technical conditions to use the float methodology. Site 4 had a mean flow of 5.1 m^3/s and 3.3 m^3/s during the wet and dry season, respectively. Site 5 had a mean flow of 9.4 m^3/s and 4.5 m^3/s for wet and dry season, respectively. The higher flows that were observed during spring could be explained by the rainy season in the region. The baseflow between rainfall events varied with the frequency of high-flow events and with seasonal changes in evapotranspiration (Yang et al., 2007). All processes which occur in the watershed are closely connected with hydrological conditions (Wang et al., 2005). Authors observe that landscapes in the watershed can determine the hydrological dynamics of water flow transporting in the flow pathways. The change of flow velocity and runoff volume plays important roles in the transporting process, detention time and export load of pollutants. As a system composed of many types of buffer/detention landscape structures, the latter can cause decline in conduit capacity and an increase in the retention of water and N pollutants through their hydrological control on flow velocity and runoff volume.

There is a relation between rainfall, river flow, and water quality. In this situation nonpoint sources will impact water quality parameters increasing concentrations. But, mainly between Years 2 and 3, EAC promoted the recuperation of riparian buffers. Thus we can observe an improvement of water quality.

Higher flow rates were observed in spring and summer which is consistent with the historical average rainfall in the region (Table 5). During the dry season water availability, mainly in Sites 1 and 2, were significantly reduced making it difficult to collect samples. The worst water quality occurred in the autumn, with EC, turbidity, and COD had the highest values while winter presented the highest values for TDS, nitrate, and nitrite.

These results could be explained by the differences in monthly average rainfall and difference in river flow during these seasons. Low flow could increase the concentration of dissolved nutrients in the water column, but high flow could enhance the erosion and runoff. The highest concentrations of solids and nitrogen during dry season could be explained by the intense use of pig manure while preparing the land before planting corn that would normally occur between August and September. Despite the producers' adoption of no-till system for their corn production, which is known to reduce erosion and runoff, the lack of riparian zone may still expose water resources to non-point or point-source pollutions.

Brazil does not have historical water quality monitoring studies and tradition to evaluate environmental actions and programs rendering it difficult to compare our results with other Brazilian studies in similar regions. Table 6, shows means of all Sites during Years 1, 2, and 3.

Table 6. Means of each water quality parameter during Years 1, 2, and 3.

Parameter	Year 1	Year 2	Year 3
Flow (m^3/s)	3.0±0.80 B	6.9±1.13 A	5.6±1.35 A
DO (mg/L)	8.0±0.09 A	6.7±0.08 C	7.3±0.21 B
Temperature (^0C)	18.5±0.25 B	18.0±0.23 C	19.1±0.15 A
pH	7.00±0.02 B	7.27±0.05 A	7.30±0.06 A
Conductivity (µs/cm)	82.0±2.4 B	102.0±5.3 A	97.0±20.1 AB
TDS (mg/L)	130.3±5.4 A	137.1±3.9 A	99.8±3.5 B
Turbidity (NTU)	36.6±4.8 A	44.4±7.3 A	15.0±2.0 B
COD (mg/L)	6.2±1.8 A	6.3±1.3 A	5.2±1.3 A
Nitrate (NO_3-N mg/L)	1.8±0.06 A	1.8±0.06 A	1.5±0.09 B
Nitrite (NO_2-N mg/L)	0.032±0.012 A	0.018±0.002 A	0.033±0.004 A
TP (mg/L)	0.290±0.012 A	0.116±0.012 B	0.102±0.012 B
TC (UFC/100ml)	713±474 A	131±49 A	149±80 A
FC (UFC/100ml)	303±178 A	88±39 A	73±40 A
E. coli (UFC/100ml)	410±297 A	44±11 A	76±41 A
Salmonella (%)	61±4 A	59±5 A	42±6 B

DO- Dissolved Oxygen; TDS- Total Dissolved Solids; COD- Chemical Oxygen Demand; TP- Total Phosphorus; TC- Total Coliforms; FC- Fecal Coliforms. Means in lines within each subheading followed by common letter(s) are not significantly different from each other at p≤0.05.

Pinhal River is fit as a Class 2 river (Brasil, 2005). Dissolved oxygen, pH, turbidity, TDS, nitrate, and nitrite were within the guideline values for Class 2 waters. Site 2 showed the best water quality. It indicates the importance of natural forest preservation and fulfills environmental legislation. Site 1 had the worst water quality because of high concentrations of turbidity, TDS, EC, DO, COD, and nitrite.

Dissolved oxygen isn’t a good parameter to evaluate water quality in rivers at Alto Uruguai Catarinense region because the landscape is very rugged which gives a high level of waterfalls in the rivers. The minimum mean concentration was verified in Year 2 and the maximum in Year 1, both are enough to keep the biodiversity and promote chemical process as nitrification.

Water temperature shows a significant variation between the Years. Santa Catarina is one of the coldest States in Brazil thus their rivers waters have lower temperatures. Only in sites 5 and 8, Pinhal river receives directly sunlight. In the other sites, there are riparian buffers that shade the water.

Water quality parameters described above show that there weren’t great variation between the years, despite significant differences verified to them. Values preserved good ecological condition and keeping water quality parameters in accordance with the standards of

Brazilian Water Law. Therefore, these parameters are important to understand the river water quality status, but aren't sufficient to evaluate EAC actions effectively.

Conductivity is influenced by natural and human activities. In this sub-basin, human activities are: agriculture, industry, and sewage. We know that between years, some environmental management were done to control non-point sources as recovery riparian buffers that prevent the transport of soil particles to water thus it contributed to reduce the influence from natural and human activities.

Between Year 2 and 3, rainfall reduced and pig farmers started to recover the riparian buffer. Analyzing the results to each Site, we can detect the importance of keep riparian zone. Site 2 presented the lowest values to TDS and Turbidity, because there weren't human activities in this Site and forest around was always present. Site 1 had the highest values, because the access that dairies and sheep had to the river. Miller et al. (2010) the overall riparian health of the fenced reach was improved by cattle exclusion. It is possible that improved riparian health may have increased the filtering or buffer capacity of the fenced reach for surface runoff from the adjacent land or water flowing in the river.

Nutrient concentrations in drainage and runoff water from agricultural land depend on complex combinations of factors; agricultural management in the preceding year, soil covering in the actual year, amount/intensity of precipitation, soil profile characteristics, drainage systems, runoff caused by topography, field size and barriers in the landscape. Other factors that should be taken into account in the case of N are ammonification and denitrification, and in the case of P, binding to the soil profile (Ulén and Folster, 2007). Wolia et al. (2004) the increase in proportion of forests decreased NO_3-N concentration.

Brazilian Water Law determines that maximum concentration of nitrate is 10 mg/L of NO_3-N and 1.0 mg/L NO_2-N. During Years 1, 2, and 3 these standards weren't reach. Maximum was 2.5 NO_3-N and 0.1 NO_2-N. Year 1 presented the highest concentrations and Year 3 the lowest to nitrate. It could be an indicator that environmental management fomented by EAC as take off tank of pig waste from riparian zone, educated farmers in use of wastes as fertilizer, and recovery riparian buffer, reduce the point and nonpoint sources from pig farms.

Year 3 presented the highest concentrations nitrite-nitrogen. We know that nitrite is an indicator of recent pollution. Data about nitrogen forms in soil and ground water could help us understand the cycle of nitrogen in the sub-basin and physiochemical, biological, and hydrological factors that are influencing nitrate and nitrite concentrations in the river.

Over daily, seasonal, and annual time scales, streamflow conditions and nitrate concentrations and loads are known to vary considerably. Many investigators have described variable nutrient fluxes in agricultural watersheds. Transport of nitrate has been shown to vary markedly with season and vary due to geologic controls on groundwater discharge and land use differences. Inputs from storm events further accentuate intermittent loading of nonpoint source pollutants (Zhang and Schilling, 2005). Runoff from agricultural farms was a major source of N entering rivers, lakes and coastal waters (Carpenter et al., 1998). Leaching from soil into water systems is also an important source (Jalali, 2005). The significant downward trend observed for N in Danish streams draining agricultural catchments in response to changes in agricultural practices and fertilization is interesting. Changes in agricultural management do not automatically lead to changes in nutrient loading and it may take decades in some watersheds to record reductions in nutrient loading because of high groundwater nitrate concentrations from previous heavy use of fertilisers (Tomer and Burkhart, 2003).

Only in four Sites in Year 2 and three Sites in Year 3 had concentrations of Total Phosphorus lower than legislation (0.100 mg/L). Sediments can accumulate phosphorus and their forms will be released to the water column in anaerobic conditions, that weren't observed through the years.

Between Years 1 and 2 occurred a reduction in TP, similar trend was also observed between Years 2 and 3. Site 1 has the worst concentrations, again animal access to the river showed its negative impact. Site 7 also had high concentrations because of human contributions (school, club, and cemetery). Despite the high concentrations of TP in the water, we cannot detect eutrophication process, because the hydrological characteristic of sub-basin that promotes a fast flow.

Sharpley et al. (2008) environmental impact may be exacerbated where ‘high-risk’ agricultural practices are located in close proximity to watercourses, on steep slopes or on underdrained land, which increase hydrological connectivity, resulting in greater efficiency of delivery of P and N to surface waters. The flow-weighted N and P concentrations generally increases with the proportion of agricultural land in Danish catchments without major point sources (Kronvang et al., 2005). Danish catchments may be due to the combination of great reductions in fertilizer use and improved use of animal manure, and intensive crop production with high yields.

Most Sites have improvement of water quality through the years, reducing Coliforms contamination. Site 2 had the best water quality thus far. Site 1 had the highest UFC/100ml to Total Coliforms, Fecal Coliforms, and Escherichia coli which promotes the worst water quality to these parameters through the years. This fact was observed from other water quality parameters and the reason is the same, animals that defecate and cross the river. The first management in this Site is put fences along the margins. Unfortunately, the fence was not built because farmers didn’t have the pigs nor signed with EAC.

Site 6 had the highest number of poultry head. Between Sites 5 and 6 have the highest concentrations of pig farms. Water quality on these sites showed improved quality between Year 1 and Year 2, but water quality declined between Year 2 and Year 3. Environmental pressure was higher, because an increase in stocking density.

Year 3 showed the lowest presence of Salmonellas at Sites 4, 5, and 6 while Year 2 presented the highest presence. Results show that main presence is related to Sites with pigs, poultries, and humans. Site 1 has one the lowest presence, being one of the better to this parameter. Site 2 was the best for all parameters less to Salmonella. It could indicate that there was a wildlife contribution in this Site, because the forest zone is preserved. Jamieson et al. (2004), one of the major difficulties in microbial pollution assessment is characterizing wildlife or “background” levels of contamination. Wildlife, such as waterfowl, can be a significant contributor to fecal pollution within rural watersheds.

Our results suggest that spatial pattern of bacterial water quality is evident, which can be linked to the different land uses and associated practices (in line with the presence or absence of animal activities). The highest concentrations of fecal coliforms and Escherichia coli were detected from catchment areas associated with dairy cattle, while the highest counts Salmonella were measured from catchment areas associated with swine and poultry. The overall impact of animal-based agriculture on microbiological water quality demonstrated by the results of this study may be considered a potential threat to the health of downstream recreational users and proportion of the local population of human and animals that rely on same water supplies.

Independently the contribution of spatial pattern, during de EAC, there weren’t improvements in the treatment systems to pig wastes. In all farms the only systems were tanks to keep the waste by one to 120 days and after it, manure was surface applied. This management must improve to reduce the environmental risk of waste and fertilization.

4. CONCLUSIONS

Environmental managements proposed by EAC improved water quality through the years. The main management that contributed to it was recovery of riparian zones that occurred in the second part of the period, between Years 2 and 3.

However, Pinhal River still has water quality problems related to total phosphorus concentration and presence of Coliforms and Salmonella. To change this situation, actions to preserve riparian zones and others related to manure management must continue. Farms don't have treatment systems to animal wastes and use nutrient balance to fertilize agricultural areas, change it is very important to reduce the organic pollutants on the river.

All farmers must be involved in these actions. Only in this way, water quality will be improved and environmental condition of sub-basin will be sustainable.

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