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ABSTRACT

Dairy farming in Tijuana, Baja California, Mexico has always been a significant source of income for many local farmers, it provides almost all the fresh milk consumed in the region and is a major contributor to the environment of the Tijuana River bi-national watershed.

This study presents the environmental perception of dairy producers about the generation, treatment and discharge of wastewater by their farms; it also describes the more frequent wastewater treatments and the social factors that limit the use of waste as source of energy; it provides a description of the mitigation measures of environmental pollution adopted by dairy producers and the influence of social factors (studied as environmental perception) in the adoption of novel technologies.

Keywords: Dairy farms, water, pollution, socio-economic, Tijuana, watershed

Meksika, Baja California, Tijuana'da Süt Endüstrisinin Sosyo-Ekolojik Özellikleri

ÖZET

Meksika, Baja California, Tijuana'daki yerel çiftçiler için süt hayvancılığı her zaman için önemli bir gelir kaynağı olmuştur. Ayrıca o bölgede tüketilen neredeyse tüm taze sütü sağlarken aynı zamanda Tijuana Nehri'nin iki uluslu havzası çevre için de büyük katkı sağlamaktadır.

Bu çalışma süt üreticilerinin kendi çiftlikleri tarafından üretimi, arıtması ve deşarjı yapılan atıksu hakkındaki çevre algılarını sunar; ayrıca daha fazla atık su arıtımı ve atığın enerji olarak kullanılmasının önündeki sosyal engelleri açıklar; yeni teknolojilerin benimsenmesinde süt üreticileri tarafından kabul edilen çevre kirliliğini azaltma önlemlerini ve sosyal faktörlerin etkisine açıklama sağlar.

Key words: Süt hayvancılığı, su, kirlilik, sosyo-ekonomik, Tijuana, su ayrım hattı

İçindekiler

1. INTRODUCTION

The city of Tijuana is an important urban center of 1 559 683 inhabitants (INEGI 2010) located in the State of Baja California Mexico, at approximately 32 º 24 ' latitude north and 117 ° 08' longitude west, the annual average temperature is 18.1 C and the average annual rainfall is 273.2 millimeters. It borders California, one of the most important economies of the United States of America but with one of the stringent environmental legislation of all USA. Water pollution of the Tijuana River basin has been the source of frictions between the USA and Mexico that resulted in treaties and infrastructure built specifically to mitigate the pollution originated in Mexico and reaching the US territory. Although most of the water pollution bi-national attention is focused on urban and industrial wastewater, there is also agriculture water use and pollution in the shared underground basin of the Tijuana River watershed.

Dairy farming in Tijuana, Baja California, Mexico has always been a significant source of income for many local farmers, it provides almost all the fresh milk consumed in the region and is a major contributor to the environment of the Tijuana River bi-national watershed.

This study presents the environmental perception of dairy producers about the generation, treatment and discharge of wastewater by their farms; it also describes the more frequent wastewater treatments and the social factors that limit the use of waste as source of energy; it provides a description of the mitigation measures of environmental pollution adopted by dairy producers and the influence of social factors (studied as environmental perception) in the adoption of novel technologies.

The goal of this article is to fill the void of environmental research in the livestock sector of the region, therefore opening up a wide field of analysis. The conclusions show a practical way to solve the environmental problem of dairy farming in Tijuana by helping government authorities to include the social factor in the decision making process.

Also, this research is important because of a need to finding solutions to the operation of old production systems. These old systems do not include pollution control or other environmental concerns because these have been regulated by the law only in recent times. Government must implement solutions considering the social component in the production.

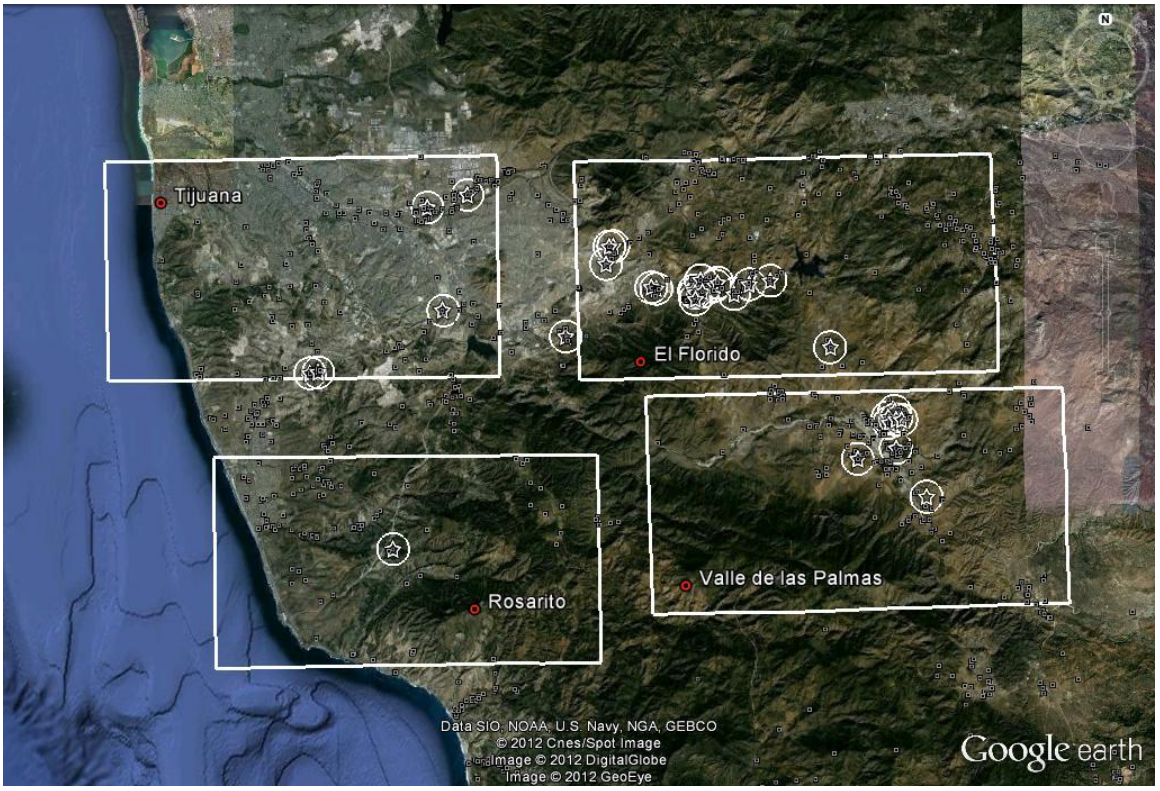
2. WATER POLLUTION CAUSED BY TIJUANA'S DAIRY FARMS

All dairy farms are located in the Tijuana River watershed a bi-national basin that also includes the main reservoir of potable water for the city of Tijuana, the Abelardo Rodriguez dam. There is a certain risk of contamination with organic matter from dairy farms that could affect the public health

of the inhabitants of the city, although the possibility of direct contamination of the reservoir is remote due to the arid characteristics of the region and the low volume of discharges, it is possible that during high rainy season, pollution from dairy farms may spread throughout the basin and reach the US territory.

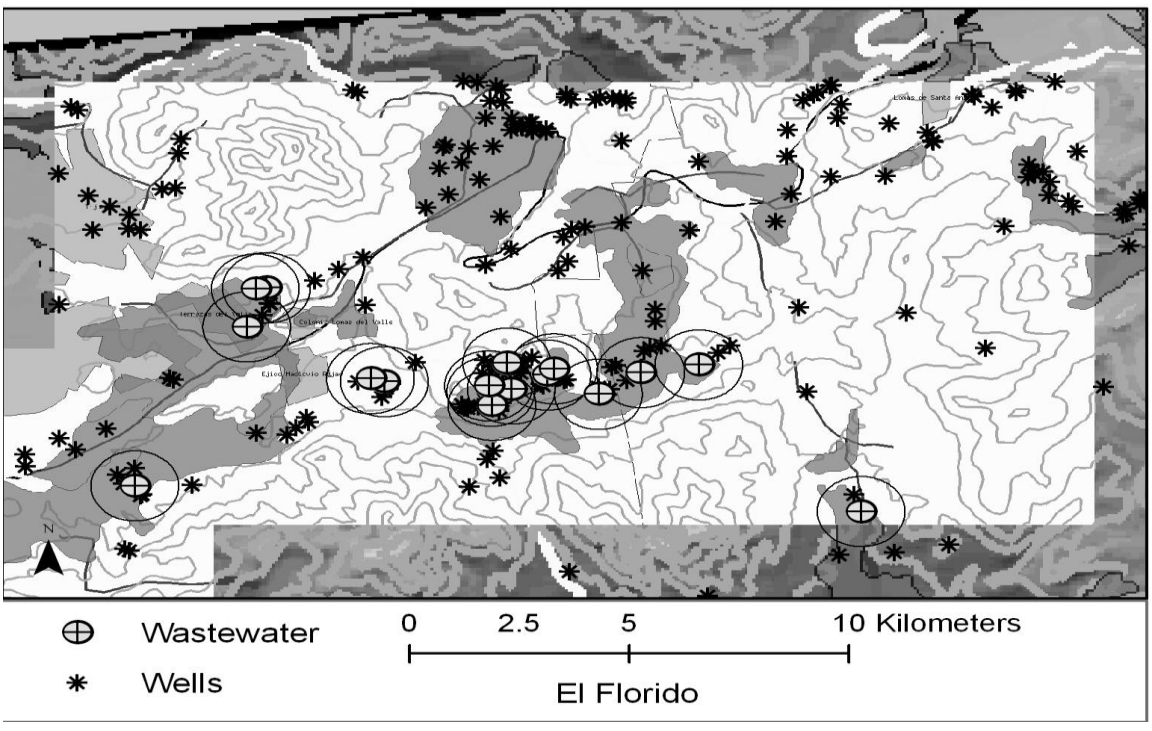
Although no data on local well water quality exists, based on worldwide experiences (Goodchild, 1998; Joosten et al., 1998; Birkinshaw and Ewen, 2000; Saãdi and Maslouhi, 2003; Kyllmar et al., 2004; Liu et al., 2005), it is highly possible that nutrient pollution of the groundwater is taking place in the aquifers of the region due to little treated dairy farms' wastewater discharges. Cattle are susceptible to nitrites and nitrates. If a cow is exposed to sufficiently high levels of nitrates/nitrites (~.55 % or greater), abortions may occur, especially in late gestation (Hoving 2009). Abortion in dairy cattle is commonly defined as a loss of the fetus between the age of 42 days and approximately 260 days. Pregnancies lost before 42 days are usually referred to as early embryonic deaths, whereas a calf that is born dead between 260 days and full term is defined a stillbirth. On dairy farms 3 to 5 abortions per 100 pregnancies per year is often considered "normal." (Hoving 2009). However, the loss of any pregnancy can represent a significant loss of (potential) income to the producer. Each abortion is estimated to cost the producer $500 to $900 - depending on such factors as the current value of replacement stock, feed and milk prices, and the stage of gestation when the abortion occurs. The contribution of nitrates in drinking water is sometimes overlooked. Nitrates in water are more toxic than plant nitrates because they are immediately available in the rumen while plant nitrates must be released from the plant cell. Consequently, toxic levels for water nitrate are lower (150-200 mg/lb body weight) than toxic levels for forage nitrate (450 mg/lb body weight) (Hibberd et al. 1994). Although there is no data on stillbirth or abortions of cattle in the Farmer's Association, anecdotic evidence suggests that it may be a factor in the local dairy farm economy.

To estimate the potential effect of nutrient contamination to the local groundwater aquifers we used data from CONAGUA (database REPDA) (CONAGUA n.d.). All stables with a permit of discharge were located in a GIS map and all wells registered in the database located within a distance of 1000 meters were selected to estimate the potential of nutrient contaminated water. Stables were grouped in four geographic areas: El Florido, Valle de las Palmas (Palms valley), Tijuana, and Rosarito. (see map)



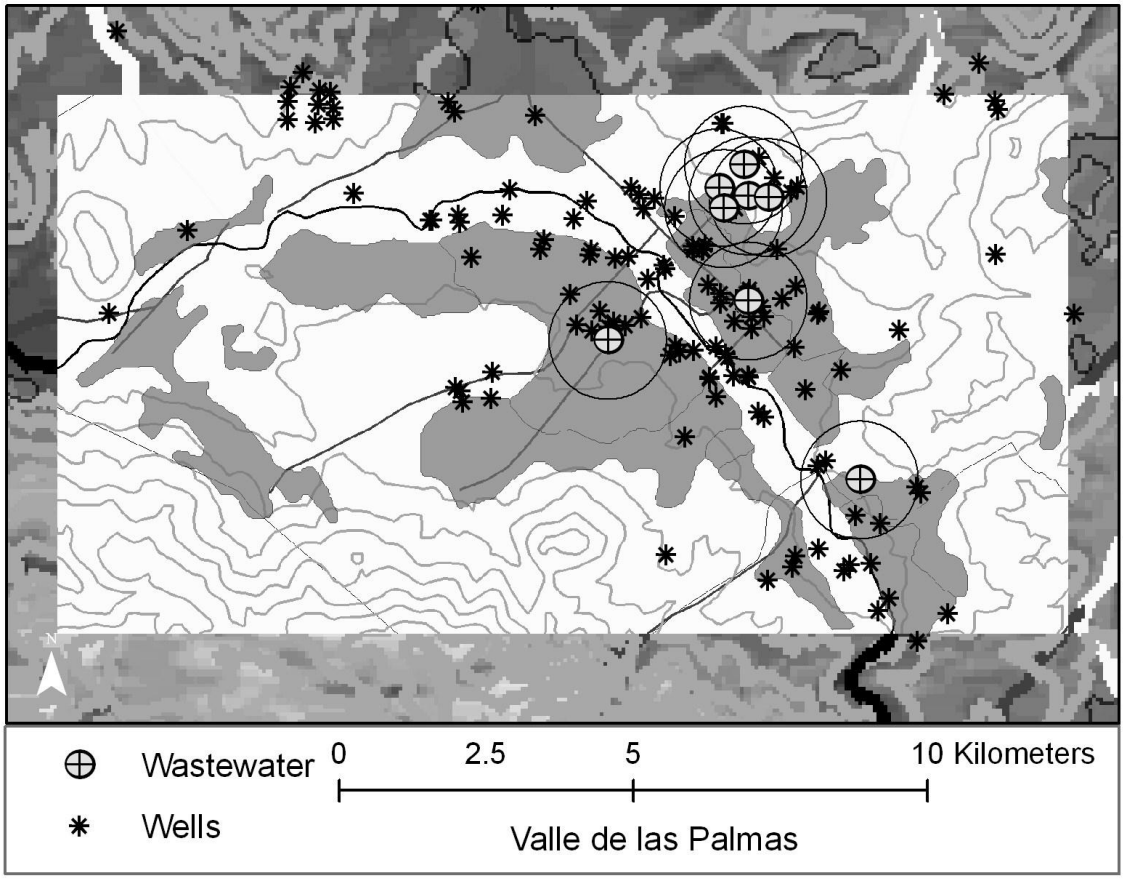
Map 1: The location of Dairy Farms in the Tijuana Region

In El Florido (see map) there are 17 stables with 9045 productive cows that generate 585.7 cubic meters per day of wastewater, with an average of 34.5 cubic meters per stable per day. In the area within 1000 meters of the stables there are 80 wells with an average depth of 140 meters that extract 3,917 cubic meters per day (1,430,041 cubic meters per year).



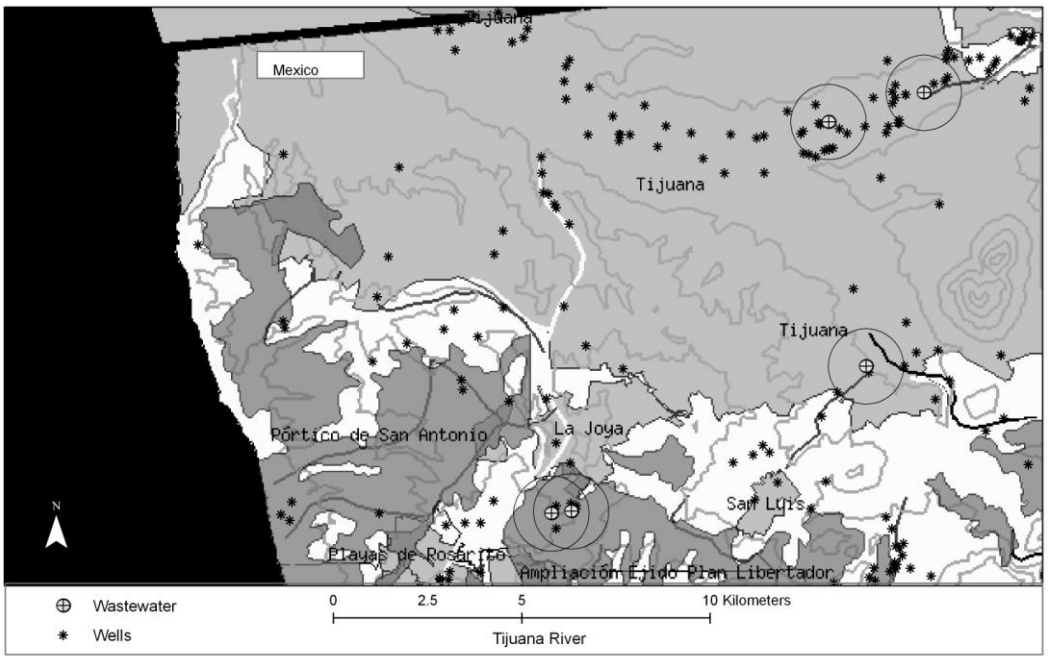
Map 2: Dairy Farms and wells in El Florido

In Valle de las Palmas (see map) there are 8 stables with 3519 productive cows that generate 324.3 cubic meters of wastewater per day, with an average of 40.5 cubic meters per stable per day. In the area within 1000 meters of the stables there are 48 wells with an average depth of 34 meters that extract 9,263.38 cubic meters per day (3,381,137 cubic meters per year).

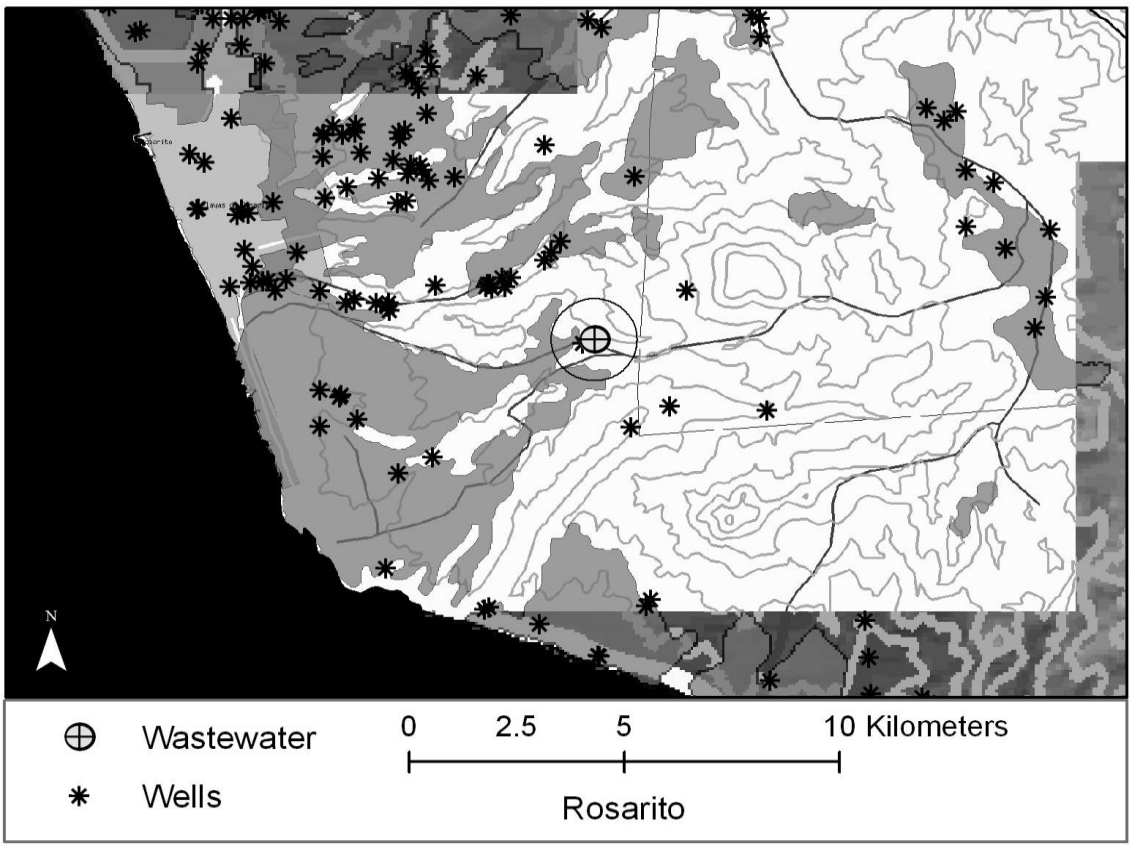


Map 3: Dairy Farms and wells in Valle de las Palmas

In Tijuana (see map) there are 5 stables with 1405 productive cows that generate 738.8 cubic meters of wastewater per day, with an average of 147.8 cubic meters per stable per day. In the area within 1000 meters of the stables there are 33 wells with an average depth of 38 meters that extract 1184.30 cubic meters per day (432,272 cubic meters per year).



Map 4: Dairy Farms and wells in Tijuana



Map 5: Dairy Farms and wells in Rosarito

The region of Rosarito was not considered because only has one stable with 220 reproductive cows and 2 wells located in the 1000 meter area with an average depth of 6 meters.

Although there is no evidence of a direct economic loss of cattle due to nutrient pollution, the possibility of reducing spontaneous abortions by reducing groundwater pollution is worth further studies. In this scenario, a possible reduction of nutrient pollution due to the installation of anaerobic digesters becomes an interesting proposition. The socio-economic factors that could influence the decision to adopt higher levels of wastewater treatment to reduce pollution were the focus of this study.

3. DAIRY FARMS WASTEWATER TREATMENT

The wastewater treatments used by dairy producers are based upon the well developed technologies of urban wastewater treatment, which includes: solids separation and a settling pond. Waste treatment in dairy farms presents a wide array of mechanisms to achieve separation and sedimentation, ranging from sophisticated patented technologies to homemade designs developed by individual farmers. Despite a large heterogeneity, all of Tijuana dairy farms have some sort of wastewater treatment.

The following tables show the regression between level of treatment (dependent variable) and the independent variables, size; importance given to environmental practices; closeness to urban areas; problems with treatment; and plans to improve the treatment in the near future.

Table 1: Variables used in the regression

Size strata = based on the number of cows ; 1 <99; 2= 100- 299; 3= 300-499; 4>500
Pressanit= presence of wastewater treatment , 1 nothing, 2 basic, 3 advanced
impenv = importance given to environmental practices; 1 none, 2 low, 3 medium 4 high
Urban = closeness to urban areas; 1 very close, 2 medium distance , 3 far
pwot= Stated problems for lack of treatment; 1 yes, 2 no
IT = Plans to Improvement treatment in the near future; 1 yes, 2 no

Table 2: Results of the regression

Coefficientsa

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.265	2.788		.095	.929
	size	.291	.309	.416	.940	.400
	impenv	-.012	.281	-.016	-.043	.968
	urban	.950	.487	.814	1.950	.123
	PWOT	-.473	.477	-.310	-.991	.378
	IT	-.210	.634	-.147	-.332	.757

a. Dependent Variable: pressanit

A regression with these variables with level of wastewater treatment (pressanit) as the dependent variable produces a model with Pearson's r of .839 and r square of .704. The resulting model is : Level of wastewater treatment = .256 (constant) - .02 importance of environmental practices - .210 Plans to Improvement treatment in the near future + .291 size - .473 Stated problems for lack of treatment + .950 closeness to urban areas.

Although the size of the operation is important in determining the level of wastewater treatment, the importance given to the environment has a larger incidence in the decision of the level of wastewater treatment, which would explain why we found that some small operations have some of the most advanced treatments in the area. Also, the more advanced the system of treatment the more likely is that they are planning to improve it in the near future. Problems with the present level of treatment doesn't show up as important in the model, it probably means that most operations are satisfied with their level of treatment and that it fulfills their legal environmental requirements.

Worldwide, the most successful technology to reduce pollution in dairy production is the anaerobic biodigester. A biodigester is a closed container where anaerobic digestion carried out. Anaerobic digestion is a series of processes in which microorganisms break down biodegradable material in the absence of oxygen, used for industrial or domestic purposes to manage waste and/or to release energy. (Merkel,1981). The digestion process begins with bacterial hydrolysis of the input materials in order to break down insoluble organic polymers such as carbohydrates and make them available for other bacteria. Acidogenic bacteria then convert the sugars and amino acids into carbon dioxide, hydrogen, ammonia, and organic acids. Acetogenic bacteria then convert these resulting organic acids into acetic acid, along with additional ammonia, hydrogen, and carbon dioxide. Finally, methanogens convert these products to methane and carbon dioxide. Most

energy in the process is preserved in the form of methane, which makes it a useful fuel to recover. The main advantage of anaerobic digestion is the conversion of waste in two products: natural gas and a stable sludge useful as fertilizer. Also, natural gas can be transformed into electrical energy. (Horn, 1981, Fontenot et al., 1983, Fang, 1990 and Kruger et al., 2008).

The dairy basin produces about 1,295 tons of manure a year. Of this amount, 57.4 percent is generated by the larger farms of more than 500 cows, 27.4 percent for the stables of between 300 and 499 cows, 13.7 percent is generated by the excreta of 100 to 299 cows, and one point five percent is generated by farms with fewer than 99 cows.

Table 3: Animal population and methane and CO2 production in Tijuana dairy stables (2011) (Source: Tijuana Dairy Farmers Association and own estimates)

Stratum	Stables	Productive cows	Dry cows	Heifers	Calves (males and females)	Sires	Total manure (kg)	Total methane (kg)	Total CO2 (ton per year)	Kw-h/year
1	5	202	47	94	131	3	19168.4	81685.6	1715.4	170339.1
2	12	2046	450	530	926	8	177405.4	681058.3	14302.2	1420211.0
3	12	4192	656	1250	1747	19	355480.4	769083.4	31321.5	3110228.2
4	13	8280	1569	3229	4478	12	743115.7	3375140.3	70877.9	7038180.0
TOTAL	42	14720	2722	5103	7282	42	1295169.9	4906967.7	118217.1	11738958.3

Total emissions of greenhouse gases in the basin are: 4907 tons per year of methane gas and 118 tons of carbon dioxide per year. The methane captured and converted to electricity through a digester would generate near 11 million kW-hours per year. Using the industrial base hours value of electricity for the region, 0.9089 pesos per kw/h (Monitor Económico de Baja California 2012) the economic potential of methane conversion to electricity is 10,669,539.2 Mexican pesos or about 800,000 dollars per year.

Based d on our open- ended interviews with key players of the industry it is clear that stable owners do not perceive their activity as a cause of pollution. It can be argued that the social factor plays a decisive role in solving environmental problems, beyond the existence of legislation that acts as a rigid mechanism.

The interview with the person in charge of the design of the wastewater treatments of the Tijuana Dairy Farmers Association indicates that the main constraint for the installation of biogas digesters is the reluctance of producers to invest in technologies with no immediate pay off. Dairy farmers

believe that the digesters are unrelated to milk production. According to the expert, producers are not interested in the biodigesters even if they reduce energy consumption in its stable.

Pollution generated by livestock in Mexico is regulated by environmental laws that focus on discharges of wastewater into the aquifers. In general, the laws regulate water pollution mainly through “command and control” mechanisms which require a payment for pollution. Mexican Official Standard NOM-001-SEMARNAT-1996 establishes the maximum permissible limits of pollutants in wastewater discharges into national waters but enforcement has always been spotty at best.

In 2007 Mexico started a national program to promote among other innovative technologies the use of anaerobic biodigesters in dairy farms, called Fideicomiso de Riesgo Compartido (FIRCO). The Shared Risk Trust (FIRCO) is a commercial government agency or parastatal created by the Mexican Agriculture Secretary of State (Secretaria de Agricultura Ganaderia, Desarrollo Rural, Pesca y Alimentación SAGARPA) in order to encourage companies to develop the agricultural sector of Mexico. The scheme is based on the concept of shared risk, which is an instrument of government policy by which financial resources are channeled towards agribusiness in order to reduce the risk involved in investing (FIRCO, 2009 (Mustieles 2010; Bonilla 2010) but it has been mostly ignored by the producers of Tijuana. In an interview with the local representative of the program, Ing Sergio Leopoldo Gonzalez Gonzalez, he stated that the lack of interest of producers is the main constraint to the expansion to the program. He also acknowledged that there are no human or financial resources to advertise existing programs.

There are private companies in Mexico to finance the construction of biogas digesters in exchange for the right to sell carbon credits on the world market. AgCert is one of the most important companies in Mexico. This company has installed five biodigesters for dairy producers in Baja California few years before (2005). The manager of Agcert was interviewed in order to explore the technological and socioeconomic difficulties in installation of digesters.

Although AgCert built five digesters in the region and most local operations are eligible to receive Mexican government FIRCO financing since they are above the lower limit of 300 animals, the manager of AgCert expressed that they are no longer interested in pursuing business in Baja California. The main reason is the level and technology of wastewater treatment used by the majority of the farms that does not allow to comply with the standards set by the Convention of the United Nations’ on Climate Change (UNFCCC, 2009) therefore making it impossible to trade carbon credits in the international market.

Dairy farmers are not convinced of the need for mitigation of environmental problems generated by its activity. Although they have a positive perception about environmental protection, they do not

feel responsible for the generation of pollution. Producers do not believe it is a priority the improvement of the present treatment of their stables.

Producers could install the digesters only if profitable agribusiness plans were established and they could generate electricity for their own profit, and although they could generate electricity for their own use, under present Mexican legislation it is almost impossible to sell the excess production to the public electric grid since the Mexican Federal Electricity Institute (Instituto Federal de Electicidad, (I.F.E.)) has a virtual monopoly of the production of electricity. However changes are currently being made to the legislation that will make possible for producers to sell their electricity to the IFE.

Not all producers are willing to invest in improvements to their waste treatment. Only young producers are interested in the economic benefits of the power saving. Older producers perceive milk production as a business totally unrelated to the treatment of waste therefore they are not interested in investing in something that does not contribute to their bottom line.

Many producers report they did not improved their treatment due to lack of financial resources. But they also stated that if financial resources were available, they would invest in food supplements and forage, milking machines or improving infrastructure. In other words unless there is a change in the present economic and legal conditions there is no incentive to upgrade the present level of wastewater treatment.

Farmers' main stated reasons for not installing or improving present waste treatment are a) Constant growth of Tijuana's urbanized area that threats to surround their operations therefore making it more profitable to sell the land to developers and move elsewhere, b) a bad economic situation that is reducing the margins of profitability; c) poor government oversight and enforcement of environmental legislation.

Waste regulations enforcement in Baja California is a complex task. It depends on scarce resources and the voluntary monitoring of indicators by the farmers themselves that hardly take place; instead the authorities accept the presence of partial treatments as enough to meet environmental regulations.

Producers do not receive sufficient information about treatments and the support offered by the government. Producers are reluctant to invest in waste treatment because they are not sure of their permanence in the milk business neither their permanence at their present location.

4. CONCLUSIONS

The milk production in the Tijuana region is a very important economic activity that generates large amounts of waste. Due to poor government oversight, the level of wastewater treatment is mostly left to individual initiatives, where large facilities tend to have higher levels of treatment but with few very honorable exceptions of small facilities sponsoring advanced levels of treatment.

Although most farmers coincide to affirm the importance of the care for the environment and the reduction of pollution, they do not perceive their activity as pollutant and are not interested in improving their present level of wastewater treatment, since there is little or no incentive to do so.

The most promising technology to reduce pollution from dairy farms is methane production. Although there is a government program that covers half the costs of installation of anaerobic digesters to produce methane there is little interest in the technology. From the farmers' point of view since there is no government pressure to improve their present level of treatment, installation of biodigesters is an expense unnecessary and that will produce no returns. The provider of the technology (AgCert) is not interested in the region since present wastewater technology of local stables is far from the minimum standards required by UNEP to commercialize Carbon Shares in the global market. The most promising use of methane gas produced in biodigesters is to generate electricity. In order to fully develop the potential of methane gas production, changes must be made in the legislation to allow dairy farmers to sell electricity produced with methane gas to the IFE, the national electric monopoly. In order to attract the attention of AgCert or any other technology provider interested in selling Carbon Shares in the international market, investments must be made to improve present levels of treatment to reach the minimum levels of the UNDEP. A combination of economic incentives and stricter enforcement of current legislation could produce the desired results.

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