

# **HISTORICAL MANURE MANAGEMENT N<sub>2</sub>O EMISSION AND ENTERIC FERMENTATION CH<sub>4</sub> EMISSION OF DOMESTIC LIVESTOCK BY COUNTRY**

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The human activities always emitted greenhouse gases, it has increased the atmospheric concentrations and the present climate change is result from past emissions. The CO<sub>2</sub> historical emissions, mainly from the energy sector and land-use change, are quite well inventoried by country, but the CH<sub>4</sub> and N<sub>2</sub>O historical emissions due to human activities are not yet well inventoried by country.

This paper presents the N<sub>2</sub>O and CH<sub>4</sub> historical emissions (1890-1998) by country due to enteric fermentation and manure management from domestic livestock of the research project “Historical Emissions of CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub> by Country”, being developed by the International Virtual Institute on Climate Change, at the Post-Graduation Coordination of the Federal University of Rio de Janeiro (IVIG/COPPE/UFRJ). Beyond this scope, we discuss some research needs related to inventorying N<sub>2</sub>O and CH<sub>4</sub> by country (e.g. rice cultivation, coal mining and natural gas) that should be historically inventoried by country.

This work shows a methodology to inventory the historical N<sub>2</sub>O and CH<sub>4</sub> emissions due to manure management and enteric fermentation. It was inventoried the emissions of those greenhouse gases by country using the HYDE (2003) domestic livestock historical database (cattle, buffalo, pigs, sheep, goats), and estimating emission factors for each animal in each country using the IPCC (1996) methodologies for inventorying the greenhouse gases emissions factors by animal, gas and process (manure and enteric fermentation). The emission factors related to each different period of time were not taken into account, meaning that from 1890 to 1998 it was considered constant for each country and animal, and future improvements are welcome. The results are expressed in Gg of CH<sub>4</sub> and Gg of N<sub>2</sub>O.

# 1 INTRODUCTION

We estimated the CH<sub>4</sub> emissions due to enteric fermentation of cattle, buffalos, pigs, sheeps, goats, horses, mules and assess by country and N<sub>2</sub>O emissions due to manure management of the above domestic livestock since 1890 until 1998. The emission follows a simple rule: the emission factor per animal multiplied for their population. The world populations of these domestic livestock's were obtained from the HYDE (2003) domestic livestock population database by country. The emission factors were based on the IPCC (1996).

These emissions are important to evaluate the contributions of countries to the present concentrations of those gases in the atmosphere and calibrate the models decay time of the gases. The following table shows the concentration of CH<sub>4</sub> and N<sub>2</sub>O before industrial revolution and in 1998:

Table 1 - N<sub>2</sub>O and CH<sub>4</sub> concentrations before the industrial revolution and in 1998

	N <sub>2</sub> O	CH <sub>4</sub>
Concentration before the industrial revolution	About 270 ppb	About 700 ppb
1998 Concentration	314 ppb	1745 ppb
Rate of changing the concentration	0.8 ppb/year	7.0 ppb/year
Lifetime in the atmosphere	114 years	12 years

Source: TAR-WGI, 2001.

## 1.1 METHANE

One of the most important sources of anthropogenic methane are the ruminants, and it is produced naturally in their digestive system, the called enteric fermentation process. In the nineties the ruminants were responsible for about 28% of all CH<sub>4</sub> anthropogenic emissions (Fung et al., 1991; Hein et al., 1997, Leviveld et al., 1998 and Howeling et al., 1999 in TAR-WGI, 2001).

We calculated the CH<sub>4</sub> emissions due to enteric fermentation of cattle, buffalo, pigs, sheep, goats, horses, mules, and assess using the HYDE (2003) domestic livestock population by country since 1890, according to the inventory methodology from the IPCC (1996).

$$E_{CH_4} \text{ (Gg/year)} = f_{CH_4} \text{ (kg/head/year)} \times P \text{ (head)} / 10^6 \text{ kg/Gg}$$

where:

$E_{CH_4}$  (Gg/year) = Emissions;

$f_{CH_4}$  (kg/head/year) = Emission factor;

P = population.

The quantity produced depends on the animal and region of world. The most important ruminants in terms of CH<sub>4</sub> emissions are the cattle, buffalo and sheep. The reference value adopted the following emission factor per animal (according to IPCC (1996) there is an uncertainty of 20% in these values):

Table 2 - CH<sub>4</sub> emission factor by animal (kg/head/year)

Type	Developed country	Developing country
Buffalo	55	55
Sheep	8	5
Goat	5	5
Horse	18	18

Mule and assess	10	10
Pig	1.5	1.0

Source: IPCC, 1996, Reference Manual, Table 4-3, page 4.10.

In the case of the cattle we used the average value of dairy and non-dairy cattle since the HYDE cattle population database has not discriminate these categories (Table 3).

*Table 3 - Cattle CH<sub>4</sub> emission factor (kg/head/year)*

Region	Type	Emission factor	Average
North America	Dairy	118	82.5
	Non-Dairy	47	
Western Europe	Dairy	100	74
	Non-Dairy	48	
Eastern Europe	Dairy	81	68.5
	Non-Dairy	56	
Oceania	Dairy	68	60.5
	Non-Dairy	53	
Latin America	Dairy	57	53
	Non-Dairy	49	
Asia	Dairy	56	50
	Non-Dairy	44	
Africa and Middle East	Dairy	36	34
	Non-Dairy	32	
Indian Subcontinent	Dairy	46	35.5
	Non-Dairy	25	

Source: IPCC, 1996, Reference Manual, Table 4-4, page 4.11.

The complete database of CH<sub>4</sub> emissions per country is very large, 200 countries, 108 years and 8 types of domestic livestock's. The accumulated emissions from the period of 1890-1998 by country, which counts with 80% of the world emissions (29 countries) is presented in the Table 4.

*Table 4 – Accumulated CH<sub>4</sub> emissions due to enteric fermentation by animal from 1890-1998 (Gg CH<sub>4</sub>)*

Country	Cattle	Buffalo	Sheep	Goats	Horses	Mules	Pigs	Assess	Total	%
U,S,A,	1,070,719	0	27,084	1,289	21,086	43	10,390	12	1,130,622	14%
India	758,899	284,579	19,835	30,296	1,890	52	547	1,323	1,097,421	13%
USSR	513,412	2,280	84,607	3,952	36,395	2	4,998	334	645,978	8%
Brazil	361,582	1,600	7,397	2,796	8,367	1,151	1,986	905	385,784	5%
China	217,165	60,241	26,116	22,394	11,613	2,207	13,123	6,312	359,171	4%
Russian Fed	267,555	127	34,223	1,709	15,878	0	2,614	23	322,130	4%
Argentina	245,946	0	21,936	1,464	12,994	202	344	253	283,139	3%
Australia	129,892	0	101,495	49	2,384	0	244	5	234,068	3%
Germany	199,520	0	4,482	1,155	5,209	0	3,353	0	213,719	3%
France	182,713	0	10,479	684	3,610	16	1,317	20	198,838	2%
Pakistan	77,454	45,372	5,648	6,762	589	25	0	1,125	136,975	2%
UK	108,725	0	23,845	0	336	0	818	0	133,723	2%
Ukraine	116,118	0	4,751	327	4,405	0	1,328	20	126,950	2%
Canada	113,773	0	880	7	3,187	2	1,361	0	119,211	1%
Bangladesh	106,843	2,740	306	4,796	0	0	0	0	114,684	1%
Italy	81,361	225	8,304	748	1,223	80	765	566	93,272	1%
Mexico	75,521	0	2,410	3,447	5,860	1,349	657	2,233	91,477	1%
Poland	75,321	0	2,341	0	5,347	0	1,610	0	84,620	1%

Colombia	77,247	0	803	362	1,979	305	159	332	81,186	1%
Kazakhstan	44,571	66	22,331	393	10,214	0	205	47	77,827	1%
Ethiopia	57,615	0	9,748	4,607	2,679	251	1	2,348	77,249	1%
Turkey	40,569	4,897	18,875	7,336	2,124	123	1	1,259	75,185	1%
Ethiopia,	53,886	0	9,163	4,993	2,679	251	1	2,651	73,624	1%
Uruguay	57,819	0	9,383	7	1,004	2	32	1	68,248	1%
New Zealand	32,960	0	33,289	58	406	0	74	0	66,788	1%
Spain	39,950	0	20,798	1,679	988	250	1,095	172	64,933	1%
South Africa	38,482	0	16,341	3,422	1,130	36	120	457	59,988	1%
Yugoslavia SFR	46,943	320	6,431	10	1,486	17	600	67	55,875	1%
Ireland	50,306	0	2,475	0	698	1	163	23	53,665	1%
<b>Total</b>	<b>5,242,869</b>	<b>402,447</b>	<b>535,777</b>	<b>104,741</b>	<b>165,758</b>	<b>6,363</b>	<b>47,905</b>	<b>20,489</b>	<b>6,526,348</b>	<b>80%</b>
<b>World</b>	<b>6,481,785</b>	<b>508,154</b>	<b>700,138</b>	<b>175,065</b>	<b>202,244</b>	<b>7,877</b>	<b>60,698</b>	<b>32,317</b>	<b>8,168,278</b>	<b>100%</b>

Source: IVIG, 2003.

Nevertheless, the accumulated emission is not a good indicator to the present contributions of the CH<sub>4</sub> concentration, once its exponential decay time is about 12 years (TAR-WG1, 2001). Therefore, we calculated the contributions to the atmospheric concentrations of CH<sub>4</sub> in the year of 1998 and we compared with the accumulated emissions for the period 1890-1998.

*Table 4 – Comparison between the concentrations and accumulated CH<sub>4</sub> emissions due to enteric fermentation from all animals (Gg CH<sub>4</sub>)*

<i>1998 CH<sub>4</sub> concentrations due to enteric fermentation from all animals (Gg CH<sub>4</sub>)</i>				<i>1890-1998 Accumulated CH<sub>4</sub> emissions due to enteric fermentation from all animals (Gg CH<sub>4</sub>)</i>		
<b>Rank</b>	<b>Country</b>	<b>Concentration 1998</b>	<b>%</b>	<b>Country</b>	<b>Accumulated Emissions</b>	<b>%</b>
1	India	168,940	13%	U,S,A,	1,130,622	14%
2	U.S.A.	150,991	12%	India	1,097,421	13%
3	Brazil	95,789	7%	USSR	645,978	8%
4	China	82,862	6%	Brazil	385,784	5%
5	USSR	75,767	6%	China	359,171	4%
6	Russian Fed	52,604	4%	Russian Fed	322,130	4%
7	Argentina	38,840	3%	Argentina	283,139	3%
8	Australia	33,561	3%	Australia	234,068	3%
9	France	27,102	2%	Germany	213,719	3%
10	Pakistan	25,620	2%	France	198,838	2%
11	Germany	22,959	2%	Pakistan	136,975	2%
12	Mexico	22,244	2%	UK	133,723	2%
13	Ukraine	21,466	2%	Ukraine	126,950	2%
14	UK	18,312	1%	Canada	119,211	1%
15	Bangladesh	17,493	1%	Bangladesh	114,684	1%
16	Canada	17,285	1%	Italy	93,272	1%
17	Colombia	17,210	1%	Mexico	91,477	1%
18	Ethiopia	15,130	1%	Poland	84,620	1%

19	Sudan	12,652	1%		Colombia	81,186	1%
20	New Zealand	12,106	1%		Kazakhstan	77,827	1%
21	Kazakhstan	11,323	1%		Ethiopia	77,249	1%
22	Italy	11,128	1%		Turkey	75,185	1%
23	Ethiopia, DPR	10,943	1%		Ethiopia, DPR	73,624	1%
24	Poland	10,002	1%		Uruguay	68,248	1%
25	Indonesia	9,626	1%		New Zealand	66,788	1%
26	Turkey	9,281	1%		Spain	64,933	1%
27	Venezuela	8,767	1%		South Africa	59,988	1%
28	Spain	8,523	1%		Yugoslavia SFR	55,875	1%
29	Uruguay	8,188	1%		Ireland	53,665	1%
	<i>Total</i>	<i>1,016,715</i>	<i>80%</i>		<i>Total</i>	<i>6,526,348</i>	<i>80%</i>
	<b>World</b>	<b>1,277,406</b>	<b>100%</b>		<b>World</b>	<b>8,168,278</b>	<b>100%</b>

Source: IVIG, 2003.

From the table above we conclude that it is more important to estimate the contributions to the concentration than just the accumulated emissions. While, South Africa, Yugoslavia and Ireland are among the top 29 accumulated CH<sub>4</sub> emitter countries, Sudan, Indonesia and Venezuela are among the 29 most contributors to the CH<sub>4</sub> concentrations in the year 1998. The positions among the top 5 countries have changed in the indicators base: the ones related to the accumulated emissions and the ones with contribution to the concentrations.

## 1.2 OXIDOUS NITROUS

In the year of 1998 the N<sub>2</sub>O emissions due to manure management were responsible for 26% of the total anthropogenic emissions of N<sub>2</sub>O (Mosier *et al.*, 1998; Kroeze *et al.*, 1999; Olivier *et al.* (1998) in TAR-WGI, 2001). We calculated the N<sub>2</sub>O emissions due to manure management of domestic livestock using the HYDE (2003) domestic livestock population by country, and the inventory methodologies of the IPCC (1996). The IPCC uses the emission factors of pigs, sheep and cattle, we calculated their N<sub>2</sub>O emissions. The formulae used is:

$$N_2O = N \times EF$$

where:

N<sub>2</sub>O = N<sub>2</sub>O emission from the animals (kg N/year);

N = number of animals;

EF = N<sub>2</sub>O emission factor (kg N<sub>2</sub>O-N/per animal).

The emission factor (EF) is function of the nitrogen excretion of the animal (IPCC, 1996, table 4.20, pages. 4.119 to 4.121) and the waste management system in the region (IPCC, 1996, table 4-21, pages 4.101 to 4.103). The N<sub>2</sub>O emission factors of the dairy and non-dairy cattle was estimated averaging them. We have used the default values of the IPCC (1996) to calculate the EF and it is summarized in the next table:

Table 4 – N<sub>2</sub>O emission factor by animal (kg/head/year)

Region	Type	EF
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<i>North America</i>	Non-dairy and dairy cattle	0.9521
	Sheep	0.296
	Pig	0.093
<i>West Europe</i>	Non-dairy and dairy cattle	0.5955
	Sheep	0.367
	Pig	0.1074
<i>Eastern Europe</i>	Non-dairy and dairy cattle	0.8393
	Sheep	0.2552
	Pig	0.1588
<i>Oceania</i>	Non-dairy and dairy cattle	1.4
	Sheep	0.4
	Pig	0.0856
<i>Latin America</i>	Non-dairy and dairy cattle	0.65635
	Sheep	0.24
	Pig	0.19648
<i>Africa</i>	Non-dairy and dairy cattle	0.9015
	Sheep	0.2406
	Pig	0.29872
<i>Near east and Mediterranean</i>	Non-dairy and dairy cattle	0.9475
	Sheep	0.24
	Pig	0.22272
<i>Asia and Far East</i>	Non-dairy and dairy cattle	0.319
	Sheep	0.2094
	Pig	0.17584

Source: prepared based on tables 4.20 and 4.21 of the IPCC, 1996, Reference Manual.

It is present the accumulated emissions for the period 1890-1998 of the countries which counts with 80% of the world emissions (34 countries).

*Table 5 - Manure management N<sub>2</sub>O emissions by animal select by countries from 1890-1998 (Gg N<sub>2</sub>O)*

Rank	Country	Sheep	Pig	Cattle	Total	
1	U.S.A.	1,002	644	8,639	10,286	9%
2	China	1,257	3,920	3,496	8,673	8%
3	USSR	2,699	529	5,320	8,548	8%
4	Australia	5,075	14	2,674	7,763	7%
5	India	831	96	5,263	6,190	6%
6	Brazil	355	390	4,164	4,909	4%
7	Russian Fed	1,092	277	2,772	4,141	4%
8	Argentina	1,053	68	2,832	3,953	4%
9	New Zealand	1,664	4	679	2,347	2%
10	Ethiopia	468	0	1,516	1,985	2%
11	Turkey	906	0	1,068	1,974	2%
12	Ethiopia , DPR	440	0	1,418	1,858	2%
13	South Africa	784	27	1,013	1,824	2%
14	UK	1,094	59	647	1,800	2%
15	Bangladesh	15	-	1,720	1,735	2%
16	France	481	94	1,088	1,663	1%
17	Germany	206	240	1,188	1,634	1%
18	Pakistan	272	-	1,247	1,519	1%
19	Ukraine	152	141	1,203	1,495	1%
20	Spain	954	78	238	1,270	1%
21	Sudan	265	-	984	1,249	1%

22	Kazakhstan	712	22	462	1,196	1%
23	Iran, Islamic Rep	756	1	393	1,149	1%
24	Uruguay	450	6	666	1,122	1%
25	Mexico	116	129	870	1,114	1%
26	Canada	33	84	918	1,035	1%
27	Poland	75	170	780	1,026	1%
28	Colombia	39	31	889	959	1%
29	Italy	381	55	485	920	1%
30	Tanzania, Un. Rep.	69	3	714	786	1%
31	Romania	297	81	384	761	1%
32	Madagascar	9	14	702	724	1%
33	Kenya	96	1	596	693	1%
34	Nigeria	76	22	585	683	1%
	<b>Total</b>	<b>24,171</b>	<b>7,200</b>	<b>57,613</b>	<b>88,984</b>	<b>80%</b>
	<b>World</b>	<b>30,143</b>	<b>8,977</b>	<b>72,290</b>	<b>111,410</b>	

Source: IVIG, 2003.

Nevertheless, the accumulated emission is not a good indicator to the present contributions of the N<sub>2</sub>O concentration, once its exponential decay time is about 114 years (TAR-WG1, 2001). Therefore, we calculated the contributions to the atmospheric concentrations of N<sub>2</sub>O in the year of 1998 and it is presented the countries that count with 80% of the world emissions.

*Table 6 - N<sub>2</sub>O concentrations due to manure management emission by country from 1890-1998 (Gg N<sub>2</sub>O)*

Rank	Country	Year 1998	%	Rank	Country	Year 1998	%
1	China	2.344	13%	15	UK	256	1%
2	U.S.A.	1.298	7%	16	Turkey	256	1%
3	Brazil	1.181	6%	17	Bangladesh	256	1%
4	Australia	1.087	6%	18	Pakistan	252	1%
5	USSR	1.076	6%	19	South Africa	240	1%
6	India	900	5%	20	France	217	1%
7	Russian Fed	684	4%	21	Iran, Islamic Rep	202	1%
8	Argentina	505	3%	22	Colombia	201	1%
9	New Zealand	405	2%	23	Nigeria	197	1%
10	Ethiopia	372	2%	24	Germany	182	1%
11	Sudan	330	2%	25	Kazakhstan	180	1%
12	Mexico	273	1%	26	Tanzania, United Rep	155	1%
13	Ethiopia , DPR	261	1%	27	Kenya	153	1%
14	Ukraine	260	1%	28	Canada	150	1%
15	UK	256	1%	29	Spain	147	1%
				30	Indonesia	143	1%
				31	Uruguay	140	1%
				32	Poland	138	1%
				33	Madagascar	118	1%
				34	Italy	114	1%
					<b>Total</b>	<b>14.675</b>	<b>80%</b>
					<b>World</b>	<b>18.380</b>	<b>100%</b>

Source: IVIG, 2003.

## **2 CONCLUSIONS AND RECOMMENDATIONS**

The CH<sub>4</sub> emissions due to enteric fermentation and N<sub>2</sub>O emissions due to manure management are better distributed among the countries than the CO<sub>2</sub> emissions due to energy. The developed countries and the countries with the big population are the larger emitters. However, the accumulated emissions are not a good indicator of contributions to climate change, due to the decay time of the gases. Related to that, the concentrations can be considered a better indicator. It was showed in the manuscript that the concentration compared to the accumulated emissions present different rankings.

It is recognized that the emission factors by animal changed during the evolution of the technologies and management practices, but it was considered constant due to the absence of references on this topic. The cattle population should be estimated in dairy and non-dairy per country once their emission factor varies a lot. It is expected partnerships to refine these values.

Energy, waste management, biomass burning and rice production CH<sub>4</sub> emission, and agricultural soils, industrial sources and biomass burning N<sub>2</sub>O emission by country should be calculated as well to estimate accurately the contribution of anthropogenic emissions by country and to refine the calibration of the decay time models of the gases.

The complete database of historic emissions for the period of 1890-1998 by country and domestic livestock, and the concentration by country and domestic livestock can be downloaded in the International Virtual Institute of Global Change web page [www.ivig.coppe.ufrj.br](http://www.ivig.coppe.ufrj.br), or by e-mail with [campos@ivig.coppe.ufrj.br](mailto:campos@ivig.coppe.ufrj.br).

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