Ammonia emissions from Agriculture in Switzerland: development between 1990 and 2010

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ABSTRACT In 1999, ammonia (NH_3) was included as an air pollutant in the Gothenburg Protocol. Member countries of the convention have to report regularly on the amount of emitted NH_3 and achieve national emission ceilings. The target for Switzerland is a reduction of 13% in the period 1990-2010. Thus, the evolution of NH_3 emissions from the agricultural production was investigated. Data on farm management was collected by means of surveys and emission calculations performed using the model AGRAMMON for 2002, 2007 and 2010. For 1990 and 1995 a simplified method was applied at the national scale. Total agricultural NH_3 emissions in 2010 were 47.6 kt N, of which livestock production contributed 90% (42.8 kt NH_3-N) and plant production 10% (4.8 kt NH_3-N). Total agricultural NH_3 emissions and emissions from livestock decreased by 17% and 15%, respectively, as compared to 1990. Cattle, pigs, poultry, horses/other equids and small ruminants accounted for 77%, 15%, 4%, 2% and 2%, respectively, of the emissions from livestock production and manure management. In 2010, the emission stages grazing, housing/exercise yard, manure storage and application produced 3%, 37%, 17% and 43%, respectively, of livestock emissions. The amount of NH_3 from grazing and housing/exercise yard increased by 87% and 48%, respectively, while emissions from manure storage and application declined by 20% and 38%, respectively since 1990. The emission reduction from livestock was mainly due to decreasing livestock numbers and more grazing which overcompensated the increase of emissions from grazing and housing/exercise yard.

Keywords: NH_3, Livestock, Farm and manure management, Emission model, AGRAMMON

INTRODUCTION Within the framework of the Convention on Long-range Transboundary Air Pollution and its protocols, parties have to regularly report their emissions and to achieve national emission ceiling values. Since 1999 ammonia (NH_3) is included as an air pollutant in the Gothenburg Protocol covering the time period 1990 to 2010. While expert assumptions for activity data on management parameters were used for the Swiss emission inventories for 1990 and 1995, emissions from 2002 onwards were based on data from representative farm surveys. Such surveys were conducted for 2002, 2007 and 2010. This data allowed the establishment of a detailed and updated time series on emissions and provide a baseline for the negotiations on a revised protocol for the time period beyond 2010. A special objective was to study the influence on NH_3 emissions of the new agricultural policy and direct payment program introduced since 1994 with environmental and animal welfare requirements.

1. MATERIAL AND METHODS

1.1. Representative farm survey for activity data The approach chosen to collect activity data for 2010 from a representative sample of farms was basically the same as described by Kupper et al. (2010a) for the surveys for 2002 and 2007. A twelve page questionnaire on livestock and manure management was distributed to a random sample of 6351 farms stratified according to three geographical regions (East, Central, West/South), three altitude zones (valley, hills, mountains) and five farm types. All in all, 2957 questionnaires (i.e. 46.6% of the distributed questionnaires) could be included in the data analysis. The Federal Office for Statistics provided activity data on livestock numbers and farming surface for these farms in an anonymous form. For 2002 and 2007 the original data from Reidy et al. (2008) and Kupper et al. (2010b) could be used. More information on the farm survey is given in Kupper et al. (2010a).

1.2. Emission calculations Emission calculations for 2002, 2007 and 2010 were individually made for each farm included in the analysis using the model AGRAMMON (Kupper et al. 2010c). AGRAMMON is a nitrogen (N) flow model that calculates emissions for grazing, housing/exercise yard, manure storage and application for 24 livestock categories. For each of the 32 classes of the survey (region x altitude x farm type) and for each livestock category an average emission factor per animal per year for grazing, housing/exercise yard, storage and application was calculated. These mean emission factors were used for upscaling emissions to the national level by multiplying them with animal numbers of the respective classes. For the time periods between the years with calculated emissions, the NH_3 production was computed by interpolation of mean emission factors and multiplying them with animal numbers of the respective years. For 1990 and 1995 a simplified calculation at the national scale was performed. Due to the difference in the applied methodology a full homogeneity of the emission time series cannot be assured.

2. RESULTS AND DISCUSSION

2.1. Emissions in 2010 Total NH_3 emissions in 2010 were 51.5 kt NH_3-N with a contribution from agriculture of 92% (47.6 kt NH_3-N). Within agriculture, livestock production and manure management contributed 90% (42.8 kt NH_3-N), the rest coming from mineral N fertilizers (2.0 kt NH_3-N), organic fertilizers (0.4 kt NH_3-N) and crop/grassland surfaces (2.4 kt NH_3-N). Cattle, pigs, poultry, horses/other equids and small ruminants accounted for 77%, 15%, 4%, 2% and 2%, respectively, of the emissions from livestock production and manure management.

2.2. Development of emissions between 1990 and 2010 Between 1990 and 2010, the total animal numbers of cattle and pigs both declined by 14% while the other livestock categories poultry, horses/other equids and small ruminants increased by approx. 50%, 150% and 20%, respectively. Since cattle and pigs excrete the major portion of TAN from livestock (e.g. 79% and 13%, respectively, for 2010) the total amount of TAN excreted declined from 87.2 kt TAN to 76.0 kt TAN (Figure 1). Other factors such as genetic progress and low protein feeds in pig and poultry production supported this trend. A clear increase of animal-friendly housing systems providing more surface per head and regular outdoor exercise using exercise yards and grazing for livestock occurred in this time period. The trend was most pronounced for the prevailing livestock categories dairy

cows and fattening pigs. By 2010, loose housing systems were used for 48% of dairy cows compared to an estimated portion of 5% in 1990. Multi-area pens with littered areas and outside exercise yard were not used for fattening pigs in the 1990s while for 2010 the portion of animals kept in such systems reached 60%.

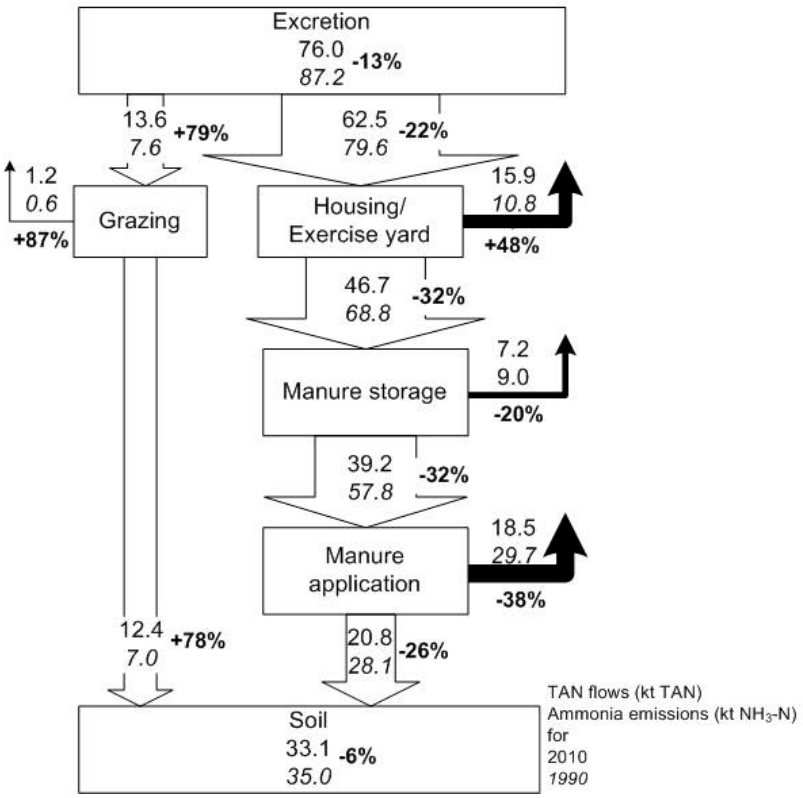

Figure 1. TAN flows (kt TAN) and ammonia emissions (kt NH_3-N) from livestock in Switzerland for 2010 (upper number) and 1990 (lower number in italics) and the difference between 1990 and 2010 in percent (%).

A share of 67% of dairy cows was estimated to be grazed in 1990. This number increased to 96% until 2010. The development of livestock management as described was similar for other livestock categories, although somewhat less pronounced. It was driven by statutory regulations aiming at an improvement of animal welfare. The extension of grazing livestock yielded an overall increase of the TAN flow into grazing by 79% and consequently, increased emissions from pastures by 87% from 0.6 kt NH_3-N to 1.2 kt NH_3-N between 1990 and 2010. More important was the impact of grazing on the TAN flow through the cascade housing/exercise yard, manure storage and application which was concomitantly reduced by 22%. Animal-friendly housing systems such as loose housings for cattle and multi-area pens with littered areas and outside exercise yard for pigs produce considerably more emissions than housings systems frequently used in 1990 (Ivanova-Peneva et al., 2008; Schrade et al., 2011). Therefore, the TAN flow into the stage housing/exercise yard produced an increase of emissions by 48% until 2010. The TAN flow into manure storage decreased from 68.8 kt TAN to 46.7 kt TAN. Due to a shift towards housing systems producing slurry instead of both slurry and solid manure an increase of the slurry storage volume by 38% occurred between 1990 and 2010. Thus, emissions from slurry storage increased by 49% and decreased by 54% for solid manure

storage. The total of emissions from manure storage was lower by 20% in 2010 as compared to 1990. The TAN flow reaching manure application declined by 32% (1990: 57.8 kt TAN; 2010: 39.2 kt TAN). Low emission spreading technologies for slurry (mainly trailing hose) were implemented and reached a share of ca. 20% for slurry application. Emissions from manure application were lower by 38% in 2010 as compared to 1990. Finally the TAN flow ending up soil from manure application was 20.8 kt TAN in 2010 corresponding to a decline by 26% since 1990. Together with the TAN remaining after grazing a total of 33.1 kt TAN produced by livestock remained in the soil. This is slightly less than the amount of TAN of 1990 which was at 35.0 kt. Overall the emissions from livestock and manure management declined from 50.1 kt NH_3-N to 42.8. kt NH_3-N which corresponds to a decrease of 15% between 1990 and 2010. In 2010, the emission stages grazing, housing/exercise yard, manure storage and application produced 3%, 37%, 17% and 43%, respectively, of livestock emissions. The corresponding numbers for 1990 were 1%, 22%, 18% and 59%, respectively. Thus, emissions tended to shift from manure application to grazing and housing/exercise yard.

Emissions from plant production decreased from 7.0 kt NH_3-N to 4.8 kt NH_3-N between 1990 and 2010. This was mainly induced by the decline of mineral fertilizer use.

3. CONCLUSION Ammonia emissions from livestock decreased by 15% between 1990 and 2010. The main drivers were a lower N flow due to reduced livestock numbers, more livestock grazing and progress in production technology such as low protein feeds and low emission slurry spreading technologies which compensated higher emissions due to increasing animal friendly housing systems.

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