Short Review

Ammonia Emissions from Non-Agricultural Sources

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Received: 19 March 2012
Accepted: 9 August 2012

Abstract

Global ammonia (NH_3) gas emissions to the atmosphere, without oceanic sources, was estimated at 44 million tons N-$NH_3 \cdot y^{-1}$, which is less than 57 million t N-$NH_3 \cdot y^{-1}$ returning to the earth's surface with atmospheric depositions. It is generally maintained that the major sources of these emissions are agricultural activities, responsible for about 75% of emissions. Although in most inventories the non-agricultural sources are generally not considered, and only agriculture is blamed. The non-agricultural sources comprise human food consumption and waste, natural vegetation, wild animals, biomass and fuel burning, mobile sources, industry, and other technical activities.

Keywords: ammonia emissions, non-agricultural sources, food consumption, waste, biomass burning

Introduction

Global ammonia (NH_3) gas emissions to the atmosphere, without the oceanic sources, was estimated at 44 million tons N-$NH_3 \cdot y^{-1}$ (Table 1) [1], which is less than 57 million tons N-$NH_3 \cdot y^{-1}$ returning to earth with atmospheric depositions [2]. It is generally claimed that the major sources of ammonia in atmosphere are agricultural activities, mainly volatilization from livestock wastes, the second major source being losses from agricultural crops, particularly those following the application of N fertilizers. But the estimations made by FAO [1] hold agriculture responsible for only 75% of these emissions, if emissions from oceans are not regarded (Table 2). A similar percentage (83%) of all ammonia produced globally was used for mineral fertilizer production [3]. Agricultural emission sources are better recognized and recorded, but remain 25% of emissions from non-agricultural sources, are poorly documented, and usually underestimated. They include numerous causes, often of small intensity or frequency. They are mostly not considered in measures taken to mitigate global and local ammonia emissions.

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The purpose of this work was to discuss the significance of non-agricultural sources of ammonia emissions and to release agriculture from responsibility.

Sources of Ammonia Emissions

The origin of ammonia emissions has a biological or technical nature. Biological sources have natural or anthropogenic character, technically only anthropogenic. Natural sources comprise areas not connected with direct human invention, including wildlife, natural ecosystems, forestry and biomass burning during natural fires of wooded areas or savannah. Agricultural and human living activity create biological anthropogenic sources. Technical sources comprise stationary and mobile fuel burning, industrial processes, and decomposition of synthetic products containing nitrogen.

Biological Sources

Agriculture

Agricultural activities as a major source of ammonia emissions into the atmosphere have been verified by numerous studies, measurements, and inventories.

Table 1. Global sources of atmospheric ammonia gas emissions from terrestrial sources [1].

Sources	Emissions mln $N\text{-}NH_3 \cdot t \cdot y^{-1}$	Percent of total emissions
Animal manure	21.6	48.6
Mineral fertilizer	9	20.3
Crops and decomposition of crops	2.6	5.9
Human waste	2.6	5.9
Soils under natural vegetation	2.4	5.4
Biomass burning, including biofuel	5.9	13.3
Fossil fuel combustion	0.1	0.2
Industrial processes	0.2	0.5
Total	44.4	100.0

Table 2. Select NH_3 emission factors for some livestock in different countries used in the RAINS model [3].

	Emission factors kg $N\text{-}NH_3 \cdot animal^{-1} \cdot y^{-1}$		
	Dairy cattle	Other cattle	Pigs
Austria	22.5	10.5	4.61
Denmark	40.9	9.8	4.29
Estonia	35.8	12.8	5.65
Germany	39.8	12.9	7.09
Italy	45.9	22.4	6.15
Netherlands	49.1	15.6	6.30
Poland	30.0	11.1	5.83
Spain	31.9	7.2	4.03
Switzerland	36.6	12.1	6.33
United Kingdom	36.5	12.9	5.66

The main stream of emissions is connected with livestock husbandry, fertilizer application, and cropping systems. Ammonia emissions from livestock start from the physiological processes in animals, through their housing, and on to animal waste handling and utilization. Emissions factors for each animal species were calculated on the basis of nitrogen content in animal waste, which is the main emission milieu. We considered that the emission factor is a defined percentage of nitrogen comprised in waste, which volatilize in the form of ammonia, depending on animal species, fodder type, and production intensity. Tables of these factors have been elaborated upon in most countries with the consideration of specific differences in their production. Some selected data collected in IIASA to be used in the RAINS model are presented in Table 2 [4]. Respective coefficients were proposed for the remaining farm animals not present in Table 2: 8 kg $N\text{-}NH_3$ animal per year for horses, from 1.33 to 2.6 kg for sheep, 1.7 kg for fur animals, and from 0.32 to 0.7 kg for poultry. These indicators comprise the effect of manure treatment, storage, and disposal.

Relevant indicators are used for mineral fertilizer application, they are split into urea and other N-fertilizers. The greatest ammonia emissions result from the application of urea fertilizers, smaller from those containing ammonium ion, and the smallest from nitrate forms (Table 3). Cropping systems, particularly legume crops and organic farming, also have an important impact of ammonia emissions, though are scarcely considered. Furthermore, ammonia emissions occur from all soils with extensive grazed sward.

Non-Agricultural Sources

Since livestock agriculture represents the major source of ammonia emissions, an interest in other sources was scarcely taken up. The estimation of non-agricultural ammonia sources has became an area of debate since atmospheric nitrogen budget estimates have suggested that the existing emissions estimates are not sufficient to balance deposition and atmospheric transport [5-7]. Ammonia emissions from non-agricultural sources have therefore been addressed to see whether they might provide the missing term in the atmospheric NH_3 budget.

Human

Human activities are next to agriculture as the greatest source of ammonia emissions. These activities cover food processing operations, catering, food consumption, and human waste utilization, as well as household use of chemicals containing ammonia. Nevertheless, they are not considered significant sources of ammonia emissions, in spite of the fact that humans are the main purchaser and consumer of food protein. These questions are scarcely mentioned in literature. People are bestowed with foodstuffs mainly of agricultural origin, but also with seafood, fowl, or naturally grown fruits and herbs. Ammonia emissions occur at each link of the human nutrition chain, beginning from the food processing industry and food preparation, through human physiology, to the waste handling and utilization as well as the use of chemicals containing ammonia in the

Table 3. Ammonia emission factors for mineral fertilizer application [3].

Fertilizer	Emissions factors, kg $N\text{-}NH_3 \cdot y^{-1}$
	% of N content in fertilizer
Ammonium sulfate	8
Ammonium nitrate	2
Urea	15
Combined fertlizers	2

household. There is limited information dealing with the impact of subsequent links on ammonia emissions, though they are significant at each step.

Ammonia emissions from foodstuff production were described only in the case of beet sugar fabrication, where an emission factor equal to 0.00262 kg $NH_3 \cdot t^{-1}$ of product was established. Ammonia does not originate from beets, but from ammonium bisulfite added for some technological reason [8]. Much greater emissions would be expected from dairy and butchery factories, especially from solid and liquid wastes rich in protein. Cooking and backing also are emission sources, as well as the rejected waste materials thrown to the dumping ground and spoiled water rinsed to sewage. A significant part of non-consumed foodstuffs is cast away into the dumping places and a smaller part into sewage. It comprises the kitchen residue and rinse as well as non-used or spoiled food. Nevertheless, the greatest ammonia emissions take place from food consumption. Normal well-fed adults exhibit a nitrogen balance where the amount of nitrogen ingested equals excreted and disposed to waste. Humans are the only consumer of all dairy and meat products (if pets are not considered).

The first information on ammonia emissions from humans originates from the early 1990s, and not much has changed in the meantime. Graf [9] proposed an ammonia emission factor from humans as high as 3.4 kg $N\text{-}NH_3 \cdot person^{-1} \cdot y^{-1}$. Moeller [10] supposed that a human emissions factor of 1.3 kg $N\text{-}NH_3 \cdot person^{-1} \cdot y^{-1}$ is underestimated. Lee and Dollard [11] summarized the available information on ammonia emissions from humans and noted that research has documented a range of 0.25 to 1.08 kg $N\text{-}NH_3 \cdot person^{-1} \cdot y^{-1}$, and assumed an ammonia release of 25 percent from human waste. They considered that a factor of 1.08 kg $N\text{-}NH_3 \cdot person^{-1} \cdot y^{-1}$ is too high, therefore they recommended use of an NAPAP [12] factor of 0.208 kg $N\text{-}NH_3 \cdot person^{-1} \cdot y^{-1}$. No other proposals were given until now. For RAINS model [4], an emission factor of 0.08 kg $N\text{-}NH_3$ per person per year has been adopted as an emission from humans. The NAPAP factor is dubious, particularly compared with much higher factors for small animals (kg $N\text{-}NH_3 \cdot animal^{-1} \cdot year^{-1}$): dog – 0.61, cat – 0.11, [8, 13], broiler – 0.167, turkey – 0.87, and rabbit – 0.017 [14]. The factors for small animals were calculated using a mass balance approach in proportion to the factors accepted for farm animals, based on nitrogen content in diet and excreted waste.

Ammonia volatilizes from the products of food digestion and is excreted with sweat, feces, and urine, immediately or after decomposition of organic substances. Ammonia is present in human breath with an emission rate of 0.003 kg $N \cdot person^{-1} \cdot y^{-1}$, and volatilized from secreted sweat at a rate of 0.012 kg $N \cdot person^{-1} \cdot y^{-1}$ [14]. A portion of sweat together with some amount of lost urine is wiped out into the lines, wherefrom ammonia is emitted and/or washed out to sewage. A small part of human waste is haphazardly dispersed in households or outside, but the main part is left in toilets, wherefrom they are directed to municipal sewage or managed in another way. Some residences have their own wastewater purification facilities. Dry toilets (latrines) are still used in some areas and only for this system was an emission factor of 2.2 kg $N\text{-}NH_3$ per person and year recognized [15]. But the main amount of domestic wastewater is collected in sewage directed into the treatment works. Most of the nitrogen entering the treatment plants is in the form of organic nitrogen and ammonia-nitrogen. However, during the treatment process, organic nitrogen is converted to NH_3 and exposed to volatilization. In oxy technologies some of NH_3 is oxidized to NO_2^- and NO_3^- during the aeration process, therefore only small atmospheric ammonia losses should be expected from aerobic processes, as pH of wastewater is maintained between 2-6. However, anaerobic microbial processes are likely to produce ammonia-nitrogen as a biological by-product of decomposition, and the pH of wastewater would rise above 7-8, and in that case ammonia emissions should dominate. Ammonia emissions from the wastewater treatment processes in southern California are estimated on the order of 1.0 mg $N\text{-}NH_3 \cdot dm^3$ of wastewater [16]. The NAPAP [12] emission inventory in USA estimated the contribution of 4.6 percent in total emissions, and rough estimates in European countries placed these contributions below 7% [6]. Efficiency of ammonia volatilization is dependent on the concentration of free aqueous ammonia ($NH_3(aq)$) that grows as pH rises [17]. The most likely fate of ammonia in influent wastewater is its uptake and consumption by microorganisms, but the ammonia released after their decomposition is vulnerable to volatilization in each method and stage of waste treatment.

Both wastewater treatment and sludge management processes were recognized as some potential source of ammonia emissions. The contribution of the publicly owned wastewater treatment plants were estimated to contribute approximately 9 to 13.5% of the total ammonia inventory in the USA [16], and European countries placed contributions below 7% [18]. An EPA document recommended using an emission factor of 1,83 kg $N\text{-}NH_3$ per 1,000 m^3 of wastewater influent [8]. Human-originated nitrogen in sewage increased from 4.5 to 5.7 kg per person per year from 1970 to 2000 [19]. Traditional wastewater treatment can remove 85-95% N from inflow waste, an average emission factor is about 0.15 g $NH_3 \cdot dm^{-3}$ [8]. Not all human waste is collected in sewage works. Some are disposed of outside water closets or leaked from sewage installations.

The lack of experimental studies and measurements was replaced by the use of mass balance equation approach [18]:

$$\text{Nitrogen Emissions} = \text{Influent Total-N} - \text{Effluent Total-N} - \text{Sludge Nitrogen Content}$$

Survey data of 850 wastewater plants in the USA showed an average 75% difference between influent and effluent concentrations of ammonia-nitrogen in wastewater treatment plants. This equates to 18.3 mg $N \cdot dm^{-3}$ of wastewater [8]. Considering that a person uses about 60 m^3 water per year, the emission factor would be 1.13 kg $N\text{-}NH_3 \cdot person^{-1} \cdot y^{-1}$, regarding that all this balance difference is emitted as ammonia. Further losses occur from sludge thrown to landfills. They were evaluated as 1.36 kg N-NH·t^{-1}·y^{-1} in the case of unprocessed sludge and 3.03 kg N-NH·t^{-1}·y^{-1} of digested sludge [8].

Ammonia emissions from non-consumed food cast to the landfill should be added to human emissions. There are small emissions of ammonia from landfill along with much larger amounts of methane and carbon dioxide. It has been estimated that the ratio of nitrogen compound emissions to methane is about 7.3%. The emitted nitrogenous gases contain NH_3, N_2O, and N_2. Of this, about 10% is ammonia, as suggested by Eggleston [20], though that seams much underestimated. The suggested dominating emissions of N_2O and N_2 is dubious as both are products of denitrification, though there is no evidence that this process prevails in dumping places due to the scarce presence of nitrates. Nevertheless, these emissions contribute about five percent to non-agricultural ammonia emissions in the UK [14]. A noteworthy part of produced and purchased food is thrown out to garbage. Each year about 90 million tons or 179 kg per capita of food waste are generated and thrown to landfills in the EU-27. These values are expected to rise. Household produce is the largest fraction of food waste at about 38 Mt per year and 76 per capita and per year; the manufacturing sector at almost 35 Mt per year and 70 kg per capita; wholesale/retail sector around 4.4 Mt (close to 8 kg per capita); and the food service sector (restaurant and catering) generates a further 12.3 Mt, or an average of 25 kg per capita [21]. Even such a frugal nation as the Swiss throws away about 40,000 tons of nitrogen annually [22]. Nitrogen content in raw food is about 0.5%, wherefrom 10-50% of N would be lost due to ammonia volatilization.

Some ammonia emission sources are household chemicals – detergents and cosmetics – evaluated as 0.025 kg per person and year [23]. The largest domestic ammonia emission is from floor screeding latex solution. In the UK this alone source emitted about 1,000 t NH_3 in 1998 [14].

Natural Vegetation and Wildlife

Natural Ecosystem Soils and Vegetation

In soils under natural vegetation many organisms that are involved in the decomposition of organic matter excrete ammonia directly, or nitrogenous compounds that readily hydrolyze to NH_3 or NH_4^+, that are exposed to emissims [24]. Ammonia emissions from natural vegetation comprise forestry, scrubland, prairies, fens, heathlands, and moorlands etc., as well as the underlying soils. Plant leaves could absorb or emit ammonia [25]. Emissions from growing plants depends on the difference between the concentration of ammonia in plants and the surrounding atmosphere, an emission takes place if it higher in growing plant and vice versa [26]. An average emission of 1.5 kg N-NH_3·ha^{-1}·y^{-1} from growing plants could be expected. This emission from the withered, damaged, or cut plants could be much greater [27]. Ammonia also is emitted from natural unfertilized soils, its emissions could attain up to 3 kg N-NH_3·ha^{-1}·y^{-1} [14, 28]. Buijsman [29] estimated a potential European ammonia emission from natural soils of 750,000 t N-NH_3·y^{-1}. The emitted amounts depend on the type of land surface. Sarwar et al. [30] elaborated on emission factors for different ecosystems in Texas (Table 4). These could not be adapted to forestry and all natural ecosystems, as currently it is unknown whether they are ammonia sinks or emitters [6]. For forests, an emission factor of 1.2 kg-NH_3·ha^{-1}·y^{-1} was selected [8]. The measurements of ammonia emissions from non-agricultural soils also are scarce, chiefly made in forest and/or abandoned soils. These emissions could be expected to increase due to the immense load of reactive nitrogen introduced with atmospheric deposition, which may amount to more than 40 kg N·ha^{-1}·y^{-1} in Europe [31]. Some reemissions of this nitrogen take place. Such reemissions were estimated for nitrous oxide (including in Poland) but not for ammonia [32, 33].

Table 4. Emission factors compiled from reviewed literature for ecosystems and soils [4].

Land surface type	Emissions factors kg N-NH_3·ha^{-1}·y^{-1}
Bare soil	3.7
Lawn surface	3.7
Urban land area	4.0
Rangeland	0.14
Oak forest	0.016
Pine forest	0.011
Coniferous forest	0.4
Scrubland	1.0

Domestic and Wild Animals

Household pets and wild animals contribute to ammonia emissions in a similar way as agricultural livestock in relation to their weight and waste excreted. In most emission inventories the input of domestic pets and wild animals is regarded. Some selected emission factors are presented in Table 5. The differences in evaluation coefficients depend on the estimation method. Some adopted animal body weight – animal unit (AU) used to calculate ammonia emissions from farm animals. Others expected that the emissions from wild animals could not be large since most ammonia is recaptured within canopies [14]. However, the grazing season is fairly included in the emission coefficients for cattle and sheep. A comparison of emission factors for humans and pets regarding the amount of nitrogen in a diet. Much more drastic is the comparison of factors 0.37, 1.8, and 0.58 kg N-NH_3·head^{-1}·y^{-1} respective for humans, dogs, and cats as elaborated – upon by a scientist collective on the basis of several papers [30]. They also suggested that dogs and cats are predicted to contribute nearly 2/3 of domestic non-industrial ammonia emissions

Table 5. Ammonia emissions factors for domestic and wild animals.

Animal species	Emissions factors kg $N\text{-}NH_3 \cdot animal^{-1} \cdot y^{-1}$	Reference
Dog	0.61	[12]
Cat	0.11	[12]
Red deer	0.9	[12]
Deer, bear, antelope	4.5	[11]
Deer, fallow-deer, moufflon	9.4	[19]
Wild hog	2.8	[19]
Rabbit	0.017	[12]
Rabbit	0.17	[11]
Badgers and foxes	0.24	[12]
Gannets, shags, cormorants	0.3	[12]
Other colony birds	0.1	[12]
Hare, pheasant, partridge	0.26	[19]

in urban counties. Domestic sources were estimated to contribute about 6% of non-point source ammonia emissions in Texas, with emissions from dog and cat urine contributing to nearly 30% of those emissions [30].

Bird waste is a significant emission source, particularly from seabirds. Seabird colony emissions ranged 1-75 kg $N\text{-}NH_3$ $hour^{-1}$, and equated to 16 and 36% volatilization of excreted nitrogen for colonies dominated by ground/burrow-nesting and bare rock-nesting birds, respectively [34]. Seabird colonies are found to represent the largest point sources of ammonia globally, estimated at up to 6,000 kg $N\text{-}NH_3$ $colony^{-1} \cdot year^{-1}$.

Burning Processes

There is evidence that during biomass burning significant amounts of ammonia are injected into the atmosphere. Several types of burning are considered: burning during forest clearing, savanna burning, peat fire, agricultural waste burning, and combustion of biofuels for energy purposes [35]. Emissions of NH_3 from biomass burning arise principally as a result of the nitrogen content of the fuel.

Coal, crude, oil, and gas derivates contains up to 2% of fixed nitrogen. Similar nitrogen content is in plant biomass. In the process of burning these materials some nitrogenous compounds are released into the gas phase, primarily as HCN, NH_3, and HNCO compounds. Oxidized nitrogen compound production prevails in high temperature processes, and reduced nitrogen, including ammonia, could be formed at lower temperatures. The average ammonia emission generated by coal combustion was evaluated as 0.40 g $N\text{-}NH_3 \cdot GJ^{-1}$ of energy [36] or as 10 kg $N\text{-}NH_3 \cdot t \cdot y^{-1}$ [37]. Other evaluations presented a lower value 1 kg $N\text{-}NH_3 \cdot t^{-1} \cdot y^{-1}$ of coal [38].

Effective ammonia emissions occur from biomass burning that currently accounts for 15% of worldwide energy consumption. Combustion of wood, charcoal, and non-woody biofuels is a daily practice for about half of the world's population, mainly due to economic reasons in developing countries. Global biofuel consumption was 4,285 million t $DM \cdot y^{-1}$ in 1993. Additionally, natural fires of forests, savannah, and peat, etc. should be considered. Lee and Atkins [39] estimated that agricultural waste burning accounts for 5 percent of the 1981 ammonia inventory for the United Kingdom.

Denmead [28] estimated that biomass combustion emissions contributed 6 to 16 percent of Australia's ammonia inventory. Other researchers indicated that biomass burning contributes up to 12 percent of the annual global flux [40]. At low air-ratio burning, a considerable amount of ammonia is created [41]. Hegg et al. [42] estimated ammonia emissions from biomass burning at about 1.81 g $NH_3 \cdot kg^{-1}$ carbon burned. This emission source may be of greater importance nowadays due to the attempts of using biomass as a renewable energy source to mitigate greenhouse gas emissions. Some amount of ammonia is created during classical industrial, commercial, and residential fuel combustion.

Mobile Sources

Ammonia emissions from gasoline cars not equipped with a catalytic converter were low for European cars – 2.2 mg $NH_3 \cdot km^{-1}$ (= 0.73 mg $NH_3 \cdot MJ^{-1}$). The introduction of catalysts have much increased ammonia emissions, approximately up to 138 in the USA [43] or 85 mg $NH_3 \cdot km^{-1}$ in Europe [14]. Two important developments for NO_x control in combustion gases are "selective catalytic reduction" (SCR), and "selective non-catalytic reduction" (SNCR). Both of these processes involve the chemical reduction of NO_x to elemental nitrogen (N_2). For the stationary and mobile sources of combustion, SCR and SNCR systems use ammonia or urea as chemical reducing agents. With either reducing agent, some ammonia remains after the NO_x reduction reaction, and is emitted in the flue gas [8]. The increase in emissions of NH_3 for catalyst cars is associated primarily with the fuel-rich combustion in the engine (<1) when hydrogen is produced due to an insufficient supply of oxygen for complete combustion. The ammonia emissions with diesel engine exhausts is much lower – about 2.9 mg $NH_3 \cdot km^{-1}$ [14].

Some findings presented at the 220th national meeting of the American Chemical Society in Washington D.C.) evidence that cars may be the main source of ammonia emissions, rather than livestock, as previously thought [43].

Technical Activities and Industry

Small ammonia emissions occur from numerous industrial, technical, and household sources. The most important industrial source is the production of nitrogenous materials, particularly chemical fertilizers but also other inorganic or organic products. Some amounts of ammonia volatilize during metal production and processing, petrochemical, fossil fuels processing (coke production, catalytic cracking), acid and halogen processes, paper/pulp manufacture, coating and printing, emissions from geothermal facilities etc., but also from some urban activities and domestic use of solvents, cleaners, cosmetics, etc. [14]. The consumption of ammonia for refrigeration applications in the U.S. is estimated at 270,000 tons per year. It is assumed that all of the NH_3 used in refrigeration is ultimately emitted to the atmosphere. Therefore, the annual emission rate for NH_3 from refrigeration also is estimated at 270,000 $Mg \cdot year^{-1}$ [8]. Some chemical synthetic products containing nitrogen: detergents, plastics, fibers, solvents, cosmetics etc., are mostly biodegradable into the key product – ammonia, that is exposed to be emitted.

Discussion

In the common outlook the main source of ammonia emissions into the atmosphere is agriculture. As a result, most experimental studies and inventories examining these emissions have focused their attention on these sources. However, each substance containing nitrogen could be the sources of ammonia emissions. Ammonia volatilization occurs at the turnover of biological substances or decomposing of synthetic nitrogenous compounds. Processes of nitrogen turnover in natural ecosystems are similar as in agriculture, only without the nitrogen input with mineral fertilizers; but the atmospheric input is alike in both systems. Human life activities comprise also biological processes – consumption and digestion of huge amounts of nitrogen-rich protein. Burning of biomass and fuel is another emission source, as well as some industrial processes and their products. The magnitude of the above-mentioned non-agricultural sources is uncertain, since there is a wide range of source types with often little underlying experimental data. Taken individually, some of these sources represent a small fraction of total emissions. However, when combined they become more important.

Non-agricultural ammonia emissions comprise human life and municipal activities, natural ecosystems, and wildlife, industry, mobile sources, and other household and technical operations. These sources are regarded in several national emission inventories, though they differ much. Their sharing was estimate as 19% in the UK [14], 19.5% in China (energy consumption only) [43], 4% in Korea [44], 1% in Denmark [45], 9% in the USA [46], and 1.9% in Poland [47]. Ignoring the importance of ammonia emissions from non-agricultural sources leads to considerable misunderstandings that could retard and make any attempts to lessen their negative impact on the environment and human health more difficult. The more so that there is need to determine the emission 'hot spots' and the ammonia critical levels in the environment [48].

It is well documented that ammonia is released from humans – from breath, sweat, and excretion as a normal metabolic process [5]. However, the experimental source strength determination were limited only to human exhaust, sweat, infant nappies, or cigarette smoke. There are data dealing with emissions from the human diet, that in developed countries include nitrogen consumption and digestion extending 5 kg N per person and year nowadays, but the proposed human emission factors are fewer than for domestic dogs. Some studies use only the nitrogen budget data from wastewater treatment plants or landfills, but no direct measurements have been made in both facilities. The operation connected with food manufacturing, storing, trading, catering, etc. should be added to human emissions as food cast away to garbage and sewage. Similar procedures were employed in calculating emission factors for farm animals, where the ammonia emission factors of 30-50% nitrogen content in animal waste was approved. Using this assumption, the proposed emission factor for humans should be close to 2.5 kg $N\text{-}NH_3$ per person and year, though its acceptance needs some more exact studies.

The chain of human life activities, particularly food manufacturing, catering, consumption and digestion, has a much greater impact on ammonia emissions than is at the present in common awareness. The amount of nitrogen involved in these activities exceide 6 kg N per capita in developed countries, and at least an ammonia emission factor of 2 kg N per capita could be expected – especially if compared to the common accepted factors for domestic pets or poultry. The data notifying ammonia emissions from human in developing countries are not available, and protein consumption there is less, though the human waste scattering is much more widespread. Considering the expected emissions factor the global ammonia emissions from human life activities could reach up to 14 million tons $N\text{-}NH_3 \cdot y^{-1}$, and more than 25 per cent of total emissions. No research data are available that could confirm or deny these realistic statements, however. Some adequate studies are needed.

The significance of natural ecosystems in ammonia emission depends on nitrogen turnover and particularly on the input vs. output equilibrium. If nitrogen input is much higher than the system demand than some export could be expected as well in the form of ammonia emissions. In opposite conditions a nitrogen sink could prevail and no ammonia emissions occur. An increasing nitrogen load is observed nowadays and a net nitrogen surplus in many ecosystem could be expected, resulting in reemissions of ammonia.

Great, not fully recognized sources of emitted ammonia are biomass and coal burning, waste incineration and both stationary and mobile uses of liquid fuel. Each type of fuel contains nitrogen that when burned at low temperature could release ammonia, and at higher temperature is produce mainly nitric oxides. Biomass combustion occurs often at lower temperatures and some ammonia emissions could be expected. A newly recognized ammonia source is transport. Emissions from vehicles were previously estimated to be rather small, but that changed after applying ammonia additives to fuel as catalytic converters in petrol and diesel engines. The use of all these sources focused proper scientific, technical, and legal attention. However, the proposed increase of the use of biomass as a substitute of non-renewable fuels needs some consideration. In this case, the ammonia emissions would accompany not only their burning, but much more their cropping.

The observed increasing nitrogen load in the atmospheric deposition [24] requires adequate measures to lessen the gaseous emissions of nitrogen into the atmosphere. The limitation of nitric oxide emissions was successfully attained, though the weaker attempts to reduce ammonia emissions were restricted only to agricultural activities. The unfavorable impact of emitted ammonia on environmental quality initiated the studies on its emission sources and processes. The studies resulted in the elaboration of emission coefficients for particular farm and wild animal species, and for applied mineral nitrogen fertilizers and cropping systems. Such coefficients were proposed for indoor emissions from humans [12], and for different non-agricultural sources [4, 11]. Nevertheless, most of these coefficients were elaborated upon more than 20 years ago and presented in February 1991 at a IIASA workshop in Austria [49], and described for Polish readers by Sapek [50]. Further revisions consisted of changes in emission coefficients, mainly lowering their values. In contemporary papers some non-agricultural sources are taken into account critically, though human beings and the linked waste management as a source of ammonia emissions are belittled, despite the fact that much could be done there to mitigate ammonia emissions.

Conclusions

1. Second to agriculture as a source of ammonia emissions is human activities including: food manufacturing, catering, consumption, and waste management. The emission factor for humans could be higher than 2 kg N-NH_3 per person annually. Unfortunately, there are only few results of research that could confirm or deny this realistic outlook.
2. Natural ecosystems could be a source or sink of atmospheric ammonia, but the emissions could prevails due to huge nitrogen input with atmospheric precipitation. Therefore, a reemission of ammonia could be expected.
3. Biomass burning and use of fuel in mobile and stationery combustion equipment is increasing emission sources, and their strength needs more investigation.

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