**[[1]](#footnote-1)Supplemental materials**

Table S1 History of previous empirical research on nitrogen flows.

Table S2 Nitrogen contents of various materials.

Table S3 NOx emission factors for the fuel types used by each socioeconomic sector.

Table S4 The Nitrogen content of foods.

Table S5 Changes in Beijing’s nitrogen consumption structure (proportion of total) from 1995 to 2015.

Supplemental references

Table S1 History of previous empirical research on nitrogen flows.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year | Content | Method | Indicators | Sources |
| 1996 | Human contributions to terrestrial nitrogen fluxes | Material flow analysis | anthropogenic nitrogen input | Jordan & Weller, 1996 |
| 2007 | The main features of the Seine river system, the physical characteristics of its drainage network and its watershed, and the nature and spatial distribution of human activities within the watershed. | Mass budget approaches and hydrological models | artificial autotrophic nitrogen / heterotrophic nitrogen | Billen et al., 2007 |
| 2007 | Analysis of human disturbance and environmental impact of the nitrogen cycle in the Yangtze River delta economic zone | Correlation analysis | reactive nitrogen / recirculating nitrogen. | Deng et al., 2007 |
| 2010 | Quantifying the utilization efficiency and losses of N and P in the Chinese food chain | NUFER (NUtrient flows in Food chains, Environment and Resources use) model | new nitrogen / recirculating nitrogen. | Ma et al., 2010 |
| 2012 | Coupling analysis of total nitrogen inputs in the environment of Shanghai and socioeconomic development factors | Coupled human and natural systems (CHANS) approach | anthropogenic nitrogen | Gu et al., 2012 |
| 2012 | Decomposition analysis of factors affecting industrial wastewater discharge in China | Logarithmic mean divisia index method | chemical oxygen demand (COD) and NH4-N from wastewater | Lei et al., 2012 |
| 2012 | Decomposition analysis of factors affecting COD and NH4-N emissions from industrial wastewater in China | Logarithmic mean divisia index method | COD and NH4-N from wastewater | Li et al., 2012 |
| 2013 | Century-scale analysis of the creation and fate of reactive nitrogen in China | National N cycle model | reactive nitrogen | Cui et al., 2013 |
| 2013 | Decomposition analysis of factors affecting emissions of implicit pollutants in China's export trade | Logarithmic mean divisia index method | SO2, COD and NH4-N nitrogen emissions implied in China's export trade | Pang et al., 2013 |
| 2014 | Decomposition analysis of factors affecting food nitrogen load in six representative countries and regions | Logarithmic mean divisia index method | food nitrogen load | Liu et al., 2014 |
| 2014 | Accounting for the net anthropogenic nitrogen input (NANI) at the city level in mainland China | NANI Model | net anthropogenic nitrogen | Gao et al., 2014 |
| 2014 | Estimating the net anthropogenic nitrogen budget for the Victoria Basin in East Africa from 1995 to 2000 | NANI Model | net anthropogenic nitrogen | Zhou et al., 2014 |
| 2016 | Evaluating the impact of food demand and rapid urbanization on net anthropogenic nitrogen production in the Huaihe River Basin | NANI Model | net anthropogenic nitrogen | Zhang et al., 2016 |
| 2017 | Decomposition analysis of factors affecting COD and NH4-N in industrial wastewater in China | Logarithmic mean divisia index method | COD and NH4-N from wastewater | Jia et al., 2017 |
| 2017 | Decomposition analysis of influencing factors of NOx emissions in China's provinces | Logarithmic mean divisia index method | NOx | Wang, 2017 |
| 2017 | Analysis of key drivers and regional dilemmas of NOx emissions in China | Logarithmic mean divisia index method | NOx | Ding et al., 2017 |
| 2018 | Comprehensive substance flow analysis of nitrogen for China in 2014 | Material flow analysis | reactive nitrogen | Luo et al., 2018 |
| 2018 | Analysis of the differences in per capita consumption and food consumption of urban and rural areas in China and their impacts on nitrogen input in food systems | Correlation analysis | food nitrogen | Gao et al., 2018 |

Table S2 Nitrogen contents of various materials.

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Value | Units | Sources |
| NOx emission factor of fuels | | - | Table S3 |
| Industrial nitrogen flux per capita | 728.8 | t per million people per year | Gu (2011) |
| N content of compound fertilizer | 30 | % | Ti et al. (2012) |
| N content of food | | - | Table S4 |
| Feeding period of livestock and poultry (days per year) | Pigs: 199 Cattle: 365 Sheep: 365 Poultry: 55 | days | Yang (2002);  Cai et al. (2005) |

Table S3 NOx emission factors for the fuel types used by each socioeconomic sector.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Emission (kg NOx/t fuel) | | | | | | Source |
|  | Household | Industry | Services | Construction | Transportation | Other |
| Coal | 1.88 | 7.50 | 3.75 | 7.50 | 7.50 | 3.75 | Kato and Akimoto (1992) |
| Coke | 2.25 | 9.00 | 4.50 | 9.00 | 9.00 | 4.50 |
| Crude oil | 1.70 | 5.09 | 3.05 | 5.09 | 5.09 | 3.05 |
| Gasoline | 16.7 | 16.7 | 16.70 | 16.70 | 21.20 | 16.70 |
| Kerosene | 2.49 | 7.46 | 4.48 | 7.46 | 27.40 | 4.48 |
| Diesel | 3.21 | 9.62 | 5.77 | 9.62 | 27.40 | 5.77 |
| Residual oil | 1.95 | 5.84 | 3.50 | 5.84 | 27.40 | 3.50 |
| Liquefied petroleum gas | 0.88 | 2.63 | 1.58 | 2.63 | 18.10 | 1.58 |
| Natural gas | 14.60 | 20.90 | 14.60 | 20.90 | — | 14.60 |
| Gasworks gas | 7.36 | 9.50 | 7.63 | 9.50 | — | 7.63 |
| Refinery gas | 0.18 | 0.53 | 0.32 | 0.53 | — | 0.32 |

Table S4 The nitrogen content of foods.

|  |  |  |
| --- | --- | --- |
| Food category | N content (% w/w) | Source |
| Cereals | 2.25 | Gao (2009) |
| Beans | 5.30 |
| Vegetables | 0.30 |
| Fruits | 0.19 |
| Pork | 2.45 |
| Beef | 2.78 |
| Milk | 2.17 |
| Mutton | 2.88 |
| Eggs | 2.06 |
| Aquaculture products | 2.18 |

Table S5 Changes in Beijing’s nitrogen consumption structure (proportion of total) from 1995 to 2015.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Year | Inorganic products (%) | Food (%) | Fertilizer (%) | Livestock feed (%) | Energy (%) |
| 1995 | 2.0 | 9.7 | 39. 5 | 11.9 | 36.9 |
| 1996 | 2.0 | 12.6 | 39.3 | 12.0 | 34.1 |
| 1997 | 2.0 | 12.5 | 40.4 | 12.5 | 32.6 |
| 1998 | 2.0 | 12.2 | 39.2 | 13.4 | 33.2 |
| 1999 | 2.0 | 12.1 | 37.8 | 14.7 | 33.4 |
| 2000 | 2.1 | 12.3 | 35.2 | 16.4 | 34.0 |
| 2001 | 2.0 | 13.9 | 28.7 | 19.6 | 35.8 |
| 2002 | 2.1 | 15.2 | 27.2 | 20.4 | 35.1 |
| 2003 | 2.2 | 15.8 | 25.5 | 20.9 | 35.6 |
| 2004 | 2.1 | 14.9 | 24.7 | 20.1 | 38.2 |
| 2005 | 2.2 | 15.6 | 25.3 | 18.3 | 38.6 |
| 2006 | 2.2 | 15.5 | 24.4 | 15.1 | 42.8 |
| 2007 | 2.3 | 16.2 | 22.5 | 11.8 | 47.2 |
| 2008 | 2.4 | 16.9 | 22.1 | 11.0 | 47.6 |
| 2009 | 2.4 | 17.4 | 21.9 | 11.1 | 47.2 |
| 2010 | 2.4 | 17.5 | 20.7 | 10.3 | 49.1 |
| 2011 | 2.5 | 18.2 | 21.5 | 10.1 | 47.7 |
| 2012 | 2.6 | 18.6 | 21.0 | 9.9 | 47.9 |
| 2013 | 2.7 | 19.8 | 20.2 | 10.0 | 47.3 |
| 2014 | 2.8 | 20.1 | 19.5 | 9.3 | 48.3 |
| 2015 | 2.9 | 20.7 | 16.4 | 8.7 | 51.3 |

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1. Note: We are willing to share these data set with those who wish to replicate the results of this research. [↑](#footnote-ref-1)