**List of Tables**

Table 1: Summary of assumptions a applied to estimate emission factors used for each vehicle category and road class in the Niger Delta (Fagbeja et al., 2013).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Vehicle category** | **Engine size (cc) / weight class** | **Fuel type** | **Av speed – highway (km/hr)** | **Av speed – major road (km/hr)** | **Av speed – minor road (km/hr)** | **Av speed – residential (km/hr)** |
| Cars | 1400 - 2000 | Petrol | 100 | 60 | 60 | 40 |
| Buses (LGVs) | All | Petrol | 80 | 50 | 50 | 30 |
| Lorries / Trailers (HGVs) | All | Diesel | 60 | 45 | 30 | 30 |
| Motorcycles (MC) | 150 - 250 | Petrol | 80 | 60 | 60 | 40 |

a Vehicle weights have been taken from weight categories available from Boulter et al (2009) based on the assumption that the majority of cars and motorcycles in the Niger Delta have small engines. Based on personal knowledge, cars, buses (LGVs) and motorcycles in the Niger Delta use petrol, and lorries / trailers (HGVs) use diesel. Average speeds of the vehicle types on the road categories were reasonable arbitrary values, due to a lack of information on speed limits for Nigeria. There was no information about the Nigerian Highway Code available from the Federal Road Safety Commission of Nigeria (FRSC) website (<http://www.frsc.gov.ng/>).

Table 2: Assumed estimated number of vehicles a for each State of the Niger Delta (Fagbeja et al, 2013).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **State** | **Population (2006)** | **Number of vehicles (2005)** | **Number of 4-wheel vehicles** | | | | **Number of 2-wheel vehicles** |
| **Cars** | **Buses** | **HGVs** | **Others** |
| Abia | 2 833 999 | 56 680 | 14 170 | 3968 | 1700 | 567 | 36 275 |
| Akwa-Ibom | 3 920 208 | 78 404 | 19 601 | 5488 | 2352 | 784 | 50 179 |
| Bayelsa | 1 703 358 | 34 067 | 8517 | 2385 | 1022 | 341 | 21 803 |
| Cross-River | 2 888 566 | 57 771 | 14 443 | 4044 | 1733 | 578 | 36 973 |
| Delta | 4 098 391 | 81 968 | 20 492 | 5738 | 2459 | 820 | 52 460 |
| Edo | 3 218 332 | 64 367 | 16 092 | 4506 | 1931 | 644 | 41 195 |
| Imo | 3 934 899 | 78 698 | 19 675 | 5509 | 2361 | 787 | 50 367 |
| Ondo | 3 441 024 | 68 820 | 17 205 | 4817 | 2065 | 688 | 44 045 |
| Rivers | 5 185 400 | 103 708 | 25 927 | 7260 | 3111 | 1037 | 66 373 |

a Estimates for the total number of vehicles are derived from the estimated population of the states in 2006 (NBS, 2009a) and the estimated 20 vehicles per 1,000 people in Nigeria in 2005 (ADF, 2007). Estimated number of cars, buses, HGVs and motorcycles in the Niger Delta based on the assumptions that in 2004, 64% all vehicles are motorcycles, 25% are cars, 7% are buses, 3% are HGVs and 1% are undefined ‘others’ (NBS, 2009b).

Table 3: Estimated disaggregated hourly traffic count a on the road classes in the Niger Delta (Fagbeja et al, 2013).

|  |  |  |  |
| --- | --- | --- | --- |
| **Road Class** | **Car** | **Bus** | **Motorcycle** |
| Highway | 1610 | 690 | - |
| Major Road | 406 | 174 | 1353 |
| Minor Road | 406 | 174 | 1353 |
| Residential Road | 147 | 63 | 490 |

a Estimates are generated based on average hourly traffic densities documented by Bada and Akande (2010), and percentage distribution of vehicles types on Nigerian roads (ADF, 2007). Estimates for highways are based on the assumption that motorcycles do not operate on highways.

Table 4: Classification of settlements in the Niger Delta into rural, semi-urban and urban classes based on population range and area benchmarks (Fagbeja et al., 2013).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Class** | **Population range** | **Lower areal extent benchmark (km2)** | **Upper areal extent benchmark (km2)** | **Number of Settlements** | **Error (%)** |
| Rural | Below 5,000 | 0.0001 | 1.0000 | 6129 | 0.5 |
| Semi-urban | 5001 to 20 000 | 1.0001 | 9.0000 | 540 | 11.3 |
| Urban | 20 001 and above | 9.0000 | 227.0000 | 49 | 8.9 |

Table 5: Settlement size categories, population estimation equations and mean errors derived from the process of establishing settlement size-population relationship. 275 settlements with known population and area estimates were used for the derivation process (Fagbeja et al, 2013).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Settlement Aerial Category** | **Settlement Class** | **Equation** | **Error (%)** | **Observations/Remarks** |
| 0 – 0.99 km2 | Rural | Population = -14.14 ln (Area) + 3882.6 | 1.8% | 65 settlements used |
| 1 to 9.99 km2 | Semi-urban | Population = 2653.4 ln (Area) + 7703.9 | 12.3% | 87 settlements used |
| 10 – 19.99 km2 | Urban | Population = 139 250 ln (Area) – 276 509 | 5.9% | 12 settlements used |
| 20 – 49.99 km2 | Urban | Population = 263 324 ln (Area) – 700 463 | 6.5% | 4 out of 6 settlements were used to derive formula. |
| 50 – 99.99 km2 | Urban | Population = 787 652 ln (Area) – 2 000 000 | 129.3% | Population of all settlement in this category are known |
| 100 km2 - above | Urban | Population = 294 790 ln (Area) – 1 000 000 | 38.3% | Population of all settlement in this category are known. |

Table 6: Percentage distribution of households a by types of fuel for cooking and types of electricity supply b for domestic lighting in the nine States of the Niger Delta in 2007. Source: NBS (2009a), NDDC (2006), Fagbeja et al, 2013.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **State** | **Estimated no. of households from emissions inventory** | **Domestic Cooking** | | | | **Domestic Lighting** | |
| **Fuel wood**  **(%)** | **Charcoal**  **(%)** | **Kerosene**  **(%)** | **Electricity and gas (%)** | **PHCN & RE**  **(%)** | **PG**  **(%)** |
| Abia | 799,505 | 73.6 | 0.0 | 25.8 | 0.7 | 44.6 | 21.6 |
| Akwa-Ibom | 574,665 | 81.0 | 0.4 | 18.3 | 0.2 | 49.0 | 12.8 |
| Bayelsa | 245,514 | 57.6 | 0.2 | 41.3 | 0.9 | 20.1 | 56.9 |
| Cross-River | 375,851 | 79.8 | 0.3 | 19.6 | 0.2 | 54.6 | 8.3 |
| Delta | 805,521 | 76.6 | 0.5 | 21.3 | 1.6 | 62.7 | 7.1 |
| Edo | 728,074 | 78.7 | 0.5 | 18.6 | 2.2 | 80.7 | 2.4 |
| Imo | 692,761 | 85.1 | 0.4 | 13.6 | 0.9 | 69.9 | 9.4 |
| Ondo | 921,325 | 66.7 | 0.3 | 32.6 | 0.4 | 58.0 | 13.0 |
| Rivers | 754,492 | 65.2 | 0.7 | 31.3 | 2.8 | 32.0 | 31.4 |
| **Total / Average** | **5,897,708** | **73.9** | **0.4** | **24.4** | **1.2** | **53.1** | **18.1** |

a The estimated number of households for the settlements located within each State of the Niger Delta has been derived by dividing the derived population of the settlements category by the average number of household per settlement category in the Niger Delta (NDDC, 2006).

b The types of electricity supply identified are PHCN – Power Holding Company of Nigeria (National Grid); RE – Rural Electrification; PG – Personal Generator

Table 7: Compilation of emission factors adopted for domestic cooking and lighting activities in the Niger Delta.

| **Activity** | **Pollutant** | **Emission Factors** | **Data source** |
| --- | --- | --- | --- |
| Cooking – Fuel wood | CO  CO2  CH4  NOx  PM10 | 30 g C/kg dry fuel  400 g C/kg dry fuel  1.5 g C/kg dry fuel  0.7 g N/kg dry fuel  3.82 g/kg dry fuel | Brocard et al., 1998  Brocard et al., 1998  Brocard et al., 1998  Brocard et al., 1998  Zhang and Morawska, 2002 |
| Cooking - Charcoal | CO  CO2  CH4  NOx  PM10 | 25 g C/kg dry fuel  170 g C/kg dry fuel  0.5 g C/kg dry fuel  0.29 g N/kg dry fuel  0.829 g/kg dry fuel | Brocard et al., 1998  Brocard et al., 1998  Brocard et al., 1998  Brocard et al., 1998  Zhang and Morawska, 2002 |
| Cooking – Kerosene | CO  CO2  CH4  NOx  PM10  SO2  VOC | 8.7 g C/kg fuel  3120 g C/kg fuel  0.0436 g C/kg fuel  0.618 g N/kg fuel  0.134 g/kg fuel  0.0331 g S/kg fuel  0.295 g C/kg fuel | Zhang et al., 2000  Zhang et al., 2000  Zhang et al., 2000  Zhang et al., 2000  Zhang et al., 2000  Zhang et al., 2000  Zhang et al., 2000 |
| Cooking – Gas/Electricity | CO  CO2  NOx  PM10  SO2 | 0.236 g C/kg fuel  3440 g C/kg fuel  2.89 g N/kg fuel  0.113 g/kg fuel  0.0014 g S/kg fuel | Zhang et al., 2000  Zhang et al., 2000  Zhang et al., 2000  Zhang et al., 2000  Zhang et al., 2000 |
| Lighting - Petrol Generator Exhaust | CO  CO2  NOx  PM10  SO2  TOC | 0.99 lb/MMBtu  154 lb/MMBtu  1.63 lb/MMBtu  0.1 lb/MMBtu  0.84 lb/MMBtu  2.1 lb/MMBtu | USEPA (1996)  USEPA (1996)  USEPA (1996)  USEPA (1996)  USEPA (1996)  USEPA (1996) |
| Lighting – Petrol Generator Evaporation | TOC | 0.09 lb/MMBtu | USEPA (1996) |
| Lighting – Petrol Generator Crankcase | TOC | 0.69 lb/MMBtu | USEPA (1996) |
| Lighting – Petrol Generator Refuelling | TOC | 0.15 lb/MMBtu | USEPA (1996) |

Table 8: Estimated daily and hourly cooking energy consumption in Nigeria assumed for the construction of emission inventory infrastructure for the Niger Delta. Source of national estimate: Anozie et al*.* (2007); hourly consumption estimate assumed by Fagbeja et al. (2013).

|  |  |  |
| --- | --- | --- |
| **Cooking fuel** | **Estimated daily consumption per household (kg)** | **Estimated hourly consumption per household (kg)** |
| Fuel wood | 0.8344 | 0.3651 |
| Charcoal | 0.8344 | 0.3651 |
| Kerosene | 0.3981 | 0.1742 |
| Cooking gas/Electricity | 0.06 | 0.0263 |

a Hourly consumption estimate is based on the assumption that cooking is carried out for 16 hours in a 7-day week.

Table 9: Comparison of the 2010 projected population estimates a obtained from 2006 National Population Census with the derived population estimates for the inventory b. Source of 2006 National Population Census and annual population growth rate: NBS, 2009b.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **State** | **2006 National Population Census Estimates** | **Projected 2010 Population Census Estimates** | **Derived 2010 Population Estimate for Inventory** | **Percentage Error (%)** |
| Abia | 2,845,380 | 3,214,955 | 5,060,759 | 36.5 |
| Akwa-Ibom | 3,902,051 | 4,408,873 | 3,564,541 | -23.7 |
| Bayelsa | 1,704,515 | 1,925,908 | 1,507,456 | -27.8 |
| Cross River | 2,892,988 | 3,268,747 | 2,435,921 | -34.2 |
| Delta | 4,172,445 | 4,714,388 | 5,200,952 | 9.4 |
| Edo | 3,233,366 | 3,653,335 | 4,586,559 | 20.3 |
| Imo | 3,927,563 | 4,437,699 | 4,706,819 | 5.7 |
| Ondo | 3,460,877 | 3,910,397 | 5,073,167 | 22.9 |
| Rivers | 5,198,716 | 5,873,957 | 4,527,540 | -29.7 |
| **Total** | **31,337,901** | **35,408,259** | **36,663,714** | **3.4** |

a Projected 2010 population estimates were derived by applying a national population growth rate of 3.1% per year.

b The derived 2010 population estimate was based on 6,718 settlements (Fagbeja et al, 2013), which is 6,614 settlements less than the number of settlements identified in the Niger Delta by NDDC (2006).

Table 10: Summary of the limitations and challenges of developing the Niger Delta Emissions Inventory infrastructure and proposed solutions

| **S/No** | **Identified Limitation / Challenge of NDEI Infrastructure Development** | **Proposed Solutions to Limitations / Challenges** |
| --- | --- | --- |
| 1 | Lack of consistent, complete, accurate and verifiable data | * Identification and coordination of public and private institutions that collect data by the Central Government body responsible for environmental monitoring and management a. This body will provide a platform for institutional interaction to determine standards and multi-sectoral mechanisms for timely collection, collation and dissemination of environmental datasets relevant for emission estimation * Strengthening environmental regulation and reporting mechanisms through legislations, and integration of these into existing institutional frameworks. * Leverage on remote sensing and Geographic Information Systems (GIS) technology to support collection of complete spatial datasets on sources of emissions and also support the development of spatially-enabled inventories b |
| 2 | Lack of access to industry- / site-specific operational / activity data, which necessitated the reliance on industry standard operations | * Funding support to carry out on-site collection of information on industrial processes, road traffic and demography, energy consumption and other data upon which more reliable assumptions could be made. This will rely on the data collection templates and mechanisms put in place as identified in Item 1 above. * Random data collection pilot study to improve the accuracy of the activity and process data for the inventory, and reduce generalizations and uncertainties in the emission estimates. * Development of appropriate emission factors localised to the Niger Delta c * Partial reconstruction of the emissions inventory, especially the point-source component of the inventory, to accommodate site-specific industrial processes that are not industry standard. |
| 3 | Lack of an Air Quality Management Framework | * An emissions inventory becomes relevant to air quality management when it exists within an air quality management framework. Therefore, a national framework for the management of air quality should be developed by the Central Government body responsible for air pollution monitoring and management. * Increased awareness and attention given to having a national emissions inventory infrastructure, which will improve technical, administrative and legislative efforts for data collection, process verification and development of methodologies towards the construction of a national inventory |
| 4 | Lack of automatic update capability in the inventory when changes are made on either the spreadsheet or GIS platform | * Building technical capacity in algorithm development to develop algorithms that can support automatic updates of changes made to the inventory on both the GIS and spreadsheet platforms c. |

a The Central Government body in Nigeria that is responsible for air quality monitoring and management is the Federal Ministry of Environment (FMEnv). Under the FMEnv, the National Environmental Standards Regulation and Enforcement Agency (NESREA) is responsible for setting air quality standards and enforcing the regulations.

b The Nigerian National Space Research and Development Agency (NASRDA) currently operates high spatial resolution satellite, NigeriaSat-2, which can support collection, mapping and updating spatial data of emission sources in Nigeria .

c The technical expertise available at the Nigerian National Space Research and Development Agency (NASRDA) can be further developed to accommodate algorithm development.