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State of the Art Emission Inventory and Their Application: Literature review

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Literature Review article

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ABSTRACT

Currently, the complex bottom-up emissions inventories are in rise. Its development is essential for both understanding the sources of air pollution and designing effective air pollution control measures. Anyway, the main challenge to get the most reliable emissions evidence is the variety of contributing sources, the complexity of the technology mix and the lack of reliable emission factors. The input data bases are improving constantly, by more reliable statistics and survey-based data. Our study reveals the strengths and deficiency of currently published scientific papers on the topic of emission inventory. With that purpose, 40 crucial scientific papers were selected. We first highlight the period and geographic region, when and where the inventories were made for. We then summarize the sector-based estimates of emissions of different species contained by SNAP sectors in selected inventories. Additionally, the resolution of inventories is analysed. Finally, the last section summarizing common ways of assessing and validating inventories and their main purpose. This review shows that there is still a lot of chance to improve emissions inventories in a way to develop input data and emission factors for different technologies and activities or to develop inventories on fine grids. Those efforts will give us wider knowledge about pollution sources and will lead to accepted better air quality policy.

Key words: Air Quality, Emission Inventory, State of the Art, Validation Process, SNAP Nomenclature

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INTRODUCTIONS

Air pollution poses important risk on our population, because it causes 6,5 million deaths per year or 1/8 of all deaths [1], [2]. According to the United Nation (UN) [3] in year 2018 around 55% of the global population lived in the urban areas. Those percentage will even increase by 60% until year 2030 and by 80% in year 2050. Consequently, the good quality of air in urban area will be important challenge in the future.

Air quality can be measured on monitoring stations using reference methods for different pollutants. Representative locations and minimum density of measurement network are determined by European commission. The accuracy of measurements obtained depends on the maintenance and monitoring of measurement equipment. [4]. The long-term observed and analysed data on permanent locations enable monitoring of improvement or deterioration of local air quality [5].

On the other hand, the spatial distribution of air quality can be assessed by using mathematical air quality models. In complex air quality models the dispersion model is coupled with detailed meteorological model, which take into account meteorological measurements and fine grid terrain information like land-use and altitude. The important part of air quality models is capability to calculate chemical transformations, which enables the model to represent the formation of secondary pollutants [6]. The crucial part, which modellers have impact on, is recognizing the emissions sources and their release, which is still currently the highest uncertainty of those models [6], [7]. Those sources are defined as points such as chimneys, lines such as roads or areas such as fields.

Emission inventory is defined as a comprehensive list of pollutants from all sources in a geographical area during a selected period of time. To get the most novel emission inventory the constant development and accuracy of input data are crucial [8]. Emission inventory can be developed on local, regional or national scale. Broad and precise inventory helps us to manage air quality through applying the most proper policy in the area. It can be used to recognize the highest sources of pollutant emissions and to determine the most endangered areas [9]. Moreover, emission inventory is useful tool for identification of the most appropriate monitoring locations and to identify the most problematic pollutants to be measured [10], [11].

The emission inventory could be conducted by two different methods, top-down or bottom-up. The more basic method is top-down, which holds information about average statistic activities, usually based on national level data, and basic emission factors for those activities. This method is used for rigid spatial distribution and to analyse national or regional emissions [12]. Meanwhile, the more progressive method is bottom-up, which includes information about activity and technology for each particulate source individually and is in addition generated to the desired spatial resolution; local, regional or even national level [13].

Emission factors for different activities are collected in emission inventory guidebook and are based on the previous studies about measurement emissions during the different activities and technologies. In Europe the most common known Emission Inventory Guidebook is EMEP/EEA Emissions Inventory Guidebook from year 2019 [14]. The guidebook holds information about emission factors on three different complex stages. Stage 1 or TIER 1 holds information about emission factors for the most basic activities and technologies. More advanced is stage 2 or TIER 2 method which includes more advanced information about activities, emission factors and technologies.

The most advances method is TIER 3, which presents the most detailed emissions input data. The stage used depends on the availability of input data and the importance of a particular source [7].

The general equation for emission estimations according to bottom-up method is the following:

$$E = A \times E_F \times \left(\frac{1 - E_R}{100}\right)$$

Where E = calculated emissions; A = activity rate needs for develop emissions; EF = emissions factor and ER = overall emission reduction efficiency (%).

Development of emission inventory following these steps:

1. Collecting the data about the sources such as vehicle fleet, national building register, national chimneys database, number and location of livestock or amount of solvent use in household;
2. determine the types of air pollutant emissions from each of the listed sources;
3. find out the emission factors for each of the concerned pollutant, which could be found in EMEP/EEA Emissions Inventory Guidebook [15];
4. determine the number and size of specific sources in the area;
5. repeat steps 3. and 4. to obtain the total emissions;
6. sum up the similar emissions and aggregate them on a desired resolution;
7. validate, analyse and interpretate given results [10].

Aim of our study is to provide an extensive literature review based on a multitude of studies on emission inventories. To the best of our knowledge, there is not yet a review covering all the aspects mentioned here. Throughout the first search the 15.157 articles were given and 40 of those were finally selected for the additional analyse. All the articles included inventory developed by bottom-up methods for anthropogenic sources.

This comprehensive article is organized as follows. Section 1 categorizes the 40 collected articles according to the period of time for which the inventory is reported. Section 2 discusses the analysed geographic area, which can be on local, regional, or national scale. Next section presents the sectors involved in the analysed inventory, which are mostly those which emitted the majority of analyzed pollutants. In this article the SNAP nomenclature was used to report sectors. The section 4 categorizes chosen articles by pollutants included in the inventory. Meanwhile, section 5 analyses the articles by their resolution. Finally, the last section summarizes common ways of assessing and validating inventories and their main purpose. Last section also includes all the additional interesting data about the particulate article. Overall view of the articles is summarized in the discussion chapter.

We believe that this literature review of emission inventories conducted on a global scale from multidisciplinary viewpoints will enable the recommendation of targeted environmental policies for maintaining good air quality, leading to healthier living in cities.

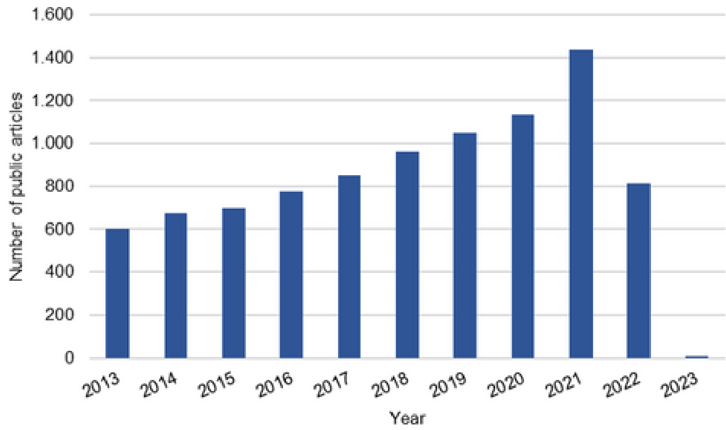
METHODS

The study is focused on the systematic review of the literature addressing the bottom-up emission inventory. The scientific articles were selected from the ScienceDirect database. The Advanced Search Builder was used and the keywords were searched in the title or abstract of the paper. We have filtered only research articles published in English language and selected the following keywords: »emission AND inventory OR evidence OR database«.

The first research found out the 15.157 articles, which are present in figure 1 by years of publication. To eliminate unfitted articles the keywords »transport AND small combustion« were added. The small combustions and transport are known as two main sources of emissions. In that way the 226 articles were selected. Additionally, the 47 articles were duplicate and eliminated.

The full-text articles were assessed for eligibility. One of the criteria was the impact factor of the journals, which should not be less than 2.5. The total of 40 eligible published research articles were obtained in their final version.

Figure 1: The number of articles search by keywords »emission AND inventory OR evidence OR database« in database ScienceDirect by year.



RESULTS

The selected scientific articles were categorized by 7 main categories and 2 subcategories. First category is the year or time period for which the inventory was developed and can be from a month to a few years long. The next category was the area where the inventory was conducted, it can be on local, regional, or national scale. Followed by sectors included in the inventory and reported in SNAP categorization, as briefly describe below. Collection of pollutants included in the study give us information about the most popular pollution covered by inventory. The important information is also the spatial resolution of the model, the most often data is in the grid form. The validation process gave us information about the most frequently used type of inventory validation. Lastly, the information about the purpose of the inventory was collected. This section additionally includes other interesting specific information about the inventories. However, to reach the information the category of article, published year and the journal, where the article was published, was added. Categorized selected articles are present in table 2.

It was decided that pollution sectors in this study will be reported using SNAP nomenclature. The English acronym SNAP stands for Selected Nomenclature for Air Pollution, that was developed under the EMEP/EEA organization in year 2001 with the purpose to synchronise the IPCC/OECD (Integrated Pollution Prevention and Control) nomenclature of source categories for activities resulting in emissions. The SNAP nomenclature is also the official nomenclature for inventory reported under the CLRTAP (Convention on Long-range Transboundary Air Pollution) convention [16]. Table 1 presents the SNAP codes and their description [14], [17].

Table 1: SNAP nomenclature and their description.

SNAP Code	SNAP Description
01	Combustion in the production and transformation of energy
02	Non-industrial combustion plants
03	Industrial combustion plants
04	Industrial processes without combustion
05	Extraction and distribution of fossil fuels and geothermal energy
06	Use of solvents and other products
07	Road Transport
08	Other mobile sources and machinery
09	Waste treatment and disposal
10	Agriculture
11	Other sources and sinks (nature)

In this study, the SNAP codes 3 and 4 are usually treated as common sources, therefore those sources are label as number 34. In the case when all SNAP sectors were used it is signed by "all SNAP sectors", meanwhile where only subcategories were used it is noted.

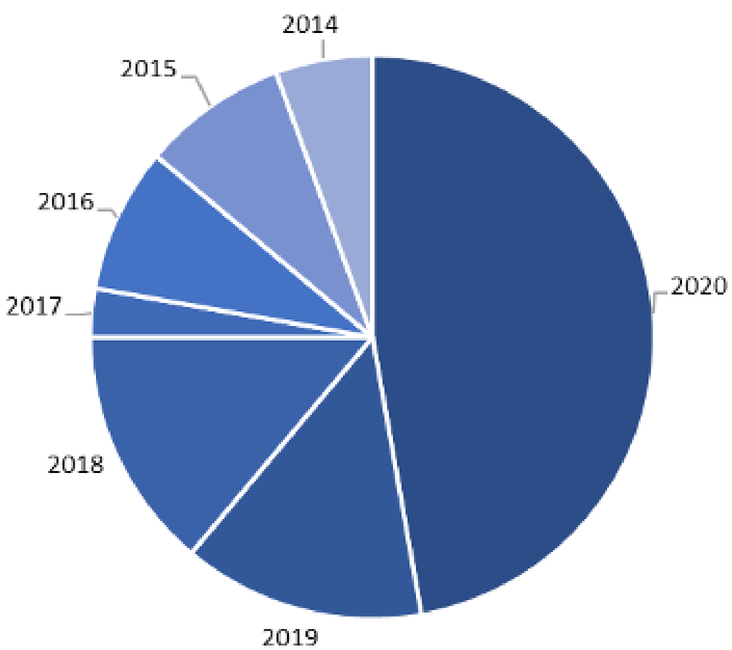
Table 2: Summary table reporting reviewed results on the topic of Emission Inventory.

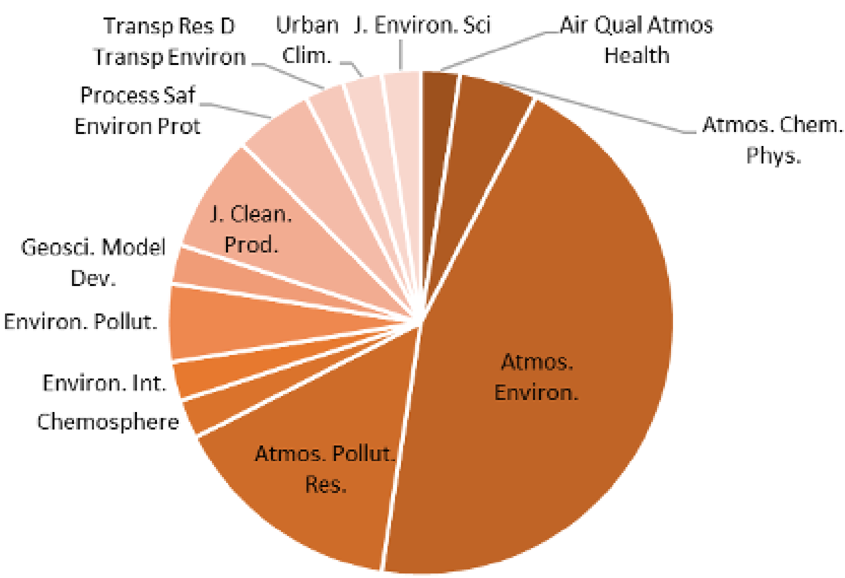
ID number	Year	Area	SNAP Sectors	Pollutants	Resolution	Validation	Purpose and other information	Year of Publication	Journal	Reference
1.	2012 and 2013	Norway: Oslo, Bergen, Trondheim, Stavanger, Drammen, Nedre Glomma, Greenland	2,34, 7, 8- ships	NOx, $PM_{2.5}$, PM_{10}	n. a.	Diamond graph	Inventory	2017	Atmos. Environ.	[7]
2	April 2017 - 2018	Tabriz (Iranian city)	1,2,3,4,5,7,8	CO, NO_x, SO_2, $PM_{2.5}$, PM_{10}, VOC	500 × 500 m	n. a.	16 scenarios	2022	J. Environ. Sci	[18]
3.	2016	Italy: Nice, Savona, Genoa, Spezia, Livorno	2, 34, 7, 8-ships, 10, 11	NOx, $PM_{2.5}$, PM_{10}	3 × 3 km	top-down inventory	CHIMERE dispersion model	2020	Atmos. Environ.	[19]
4.	2007-2009	Evropa	All SNAP sectors	O_3, NO_2, SO_2, $PM_{2.5}$, PM_{10}	8 × 8 km	Measurement network	CHIMERE dispersion model	2015	Geosci. Model Dev.	[20]
5.	2006 - 2012	Greece and Athens	All SNAP sectors	NO_x, NMVOC, CO, SO_2, NH_3, PM_{10}, $PM_{2.5}$	6 × 6 km (Greece) 2 × 2 km (Athens)	Comparison with previous bottom-up inventory	Emissions are hourly based	2016	Atmos. Environ.	[21]
6.	2008	Italy: Torino	7	CO, CO_2, SO_2, NH_3, NMVOC, $PM_{2.5}$, NO_X	n. a.	top-down inventory	Inventory	2014	Atmos. Pollut. Res.	[22]
7.	2005	EU-27	2 – biomass burning	Elemental (EC) and organic carbon (OA)	7 × 7 km	Measurement network	Dispersion model with PMCAMx and EMEP MSC-W	2015	Atmos. Chem. Phys.	[23]
8.	2003 - 2009	All countries under the CLRTAP conventional (51 countries EU and USA)	All SNAP sectors	CO, NO_x, SO_2, NH_3, NMVOC, $PM_{2.5}$, PM_{10}, CH_4	7 × 7 km	Energy use model GAINS and EDGAR	Inventory	2014	Atmos. Chem. Phys.	[24]
9	2015	1. comparison all Europe areas 2. comparison different region: Benelux, Po Valley and Balck Triangle	All SNAP sectors	NO_x, VOC, SO_x, NH_3, PM_{10}, $PM_{2.5}$	11 × 11 km	Comparison of three different models: The EDGAR database, The EMEP emissions, The CAMS-REG-AP	The benchmarking methodology, based on the comparison of modelled and measured data, developed in the frame of the FAIRMODE network	2021	Atmospheric Environment	[25]
10.	2009	Spain: Barcelona	All SNAP sectors	NO_x, SO_2, VOC, PM_{10}	7 × 7 km	Diamond graph	Inventory	2016	Air Qual Atmos Health	[26]
11	2009	France - Paris	2,7	NOx, SO_2, CO, VOC, PM	Spatial unit of Paris	AIRPARIF – regional emission inventory, EMEP	Developing of inventory Model OLYMPUS	2021	Atmos. Environ.	[27]

ID number	Year	Area	SNAP Sectors	Pollutants	Resolution	Validation	Purpose and other information	Year of Publication	Journal	Reference
12.	2010	USA California	All SNAP sectors	VOC, indirectly O_3 and PM	4 × 4 km	Data from article[28]	Dispersion model CMAQ.	2019	Atmos. Environ.	[29]
13.	2015	China: Sichuan	All SNAP sectors	VOC, indirectly O_3 and PM	1 × 1 km	n.a.	Inventory	2019	Atmos. Pollut. Res.	[30]
14.	2016	China: Harbin-Changchun	7	CO, HC, NO_x, NH_3, VOC, $PM_{2.5}$ in PM_{10}	1 × 1 km	n.a.	Scenarios	2020	Process Saf Environ Prot	[31]
15.	January and July 2010	China: Beijing, Shanghai in Guangzhou	1,2,34,7	CO, NO, SO_2, BC and organic carbon (OC)	111 × 111 km 28 × 28 km 55 × 55 km	3. previous made emission inventory: HTAPv2, REASv2 and MACCity, measurement network and satellite data	Dispersion model WRF-Chem	2018	Atmos. Environ.	[32]
16.	2015	China: Wuxi city,	2, 34,7,9,10	NO_x, SO_2, TSP, NH_3, VOCs, $PM_{2.5}$, PM_{10}, CO	1 × 1 km	4. previous made emission inventory and Monte Carlo method	Inventory	2019	J. Clean. Prod.	[33]
17.	2016	China: Shandong	1,2,34, 6,9,7	NO_x, SO_2, VOCs, $PM_{2.5}$, PM_{10}, CO	4 × 4 km	Monte Carlo method	Inventory	2020	J. Clean. Prod.	[34]
18.	2014	Greece: Delphi	1, 2-small combustion and and construction, 34, 7,8-aviation, 9	$PM_{2.5}$ including their composition	2× 2 km	n.a.	Hazard and toxicity analysis of substances	2020	Chemosphere	[35]
19.	2016	China: Henan	2	NO_x, SO_2, VOCs, $PM_{2.5}$, PM_{10}, CO	3 × 3 km	uncertainty analysis	Scenarios	2020	Atmos. Environ.	[36]
20.	December 2017	South Korea: Incheon Port	8 - ships	NO_x, SO_2, PM_{10}, CO	2 × 2 km	top-down inventory	Inventory	2018	Atmos. Environ.	[37]
21.	2015	Malaysia: Kuala Lumpur	7,34 (small industries)	NO_2, NO_x, SO_2, $PM_{2.5}$, PM_{10},	1 × 1 km	Analyse of emission relies (kg/year/person) uncertainty analysis	Inventory	2020	Atmos. Pollut. Res.	[38]
22.	n.a.	n.a.	n.a.	n.a.	n.a.	Diamond graph	Description of Diamond graph	2020	Atmos. Environ.	[39]
23.	1990 - 2008	France	All SNAP sectors	Dioxins	n.a.	Measurement network comparison with program UNEP Toolkit	Inventory	2020	Atmos. Pollut. Res.	[40]
24.	2003-2017	Nepal	11- crop residue open burning	NH_3, NO_x, SO_2, $PM_{2.5}$, CO_2, CO, OC,BC, NMVOC, CH_4	1 × 1 km	Monte Carlo method	Inventory	2020	Environ. Pollut.	[41]
25.	2010	Global word	1,2,34,7	Size distribution of PM	n.a.	uncertainty analysis	Scenarios	2015	Atmos. Environ.	[42]
26.	2010	Europe (Barcelona, Bucharest, Budapest, Katowice, London, Madrid, Milan, Paris, Sofia, Utrecht and Warsaw)	2,34,7	NO_x, SO_2, $PPM_{2.5}$, VOC	7 - 10 km	Comparison of 6 different inventory: EDGAR, TNO_MACCII, TNO-MACIII, INERSinv, EMEP, JRC07 Diamond graph	Use of Diamond graph	2018	Atmos. Environ.	[13]
27.	2017	Brazil: Santa Catarina (Florianópolis São José Palhoça Biguaçu Governor Celso Ramos)	7	CO, HC, NMHC, RCHO, NO_x, N_2O, PM, CH_4	n.a., source is line	n.p.	Scenarios	2019	Transp Res D Transp Environ	[43]
28.	At least year 2010	South America: Argentina, Brazil, Chile, Colombia and Peru	2- small combustion and construction, 34,7,10	NO_x, PM_{10}, SO_2, CO, BC in OC	city	2 emission inventory: EDGAR in ECLIPSE	Inventory	2020	Atmos. Environ.	[44]
29.	2010 and 2015	India: Kolkata	1, 2- small combustion and construction, 34,7,9,10	NO_x, SO_2, $PM_{2.5}$, PM_{10}, BC, VOC, OC, CO, NH_3	n.a.	n.a.	Scenarios	2020	Atmos. Environ.	[45]
30.	August 2013 and 2014	Turkey: Çanakkale	2,34,7, 8 - ships	PM, VOC, CO_2, CO	1 × 1 km	AERMOD and CALPUFF model	Association between air quality and morbidity of lung disease, Modelling with AERMOD	2020	Atmos. Pollut. Res.	[46]
31.	2013	Iran: Teheran	1,2,34,7	NO_x, SO_2, VOC, CO, PM	500 × 500 m	uncertainty analysis	Inventory	2016	Urban Clim.	[47]
32.	2016	Argentina	10 – manure management and crop cultivations, 11 - open burning of biomass	NO_x, $PM_{2.5}$, PM_{10}, NMVOC, NH_3	24 provinces and 512 administrative units	Emission inventory EDGAR	Inventory	2020	Atmos. Environ.	[48]
33.	2018	Iran: Isfahan	7	NO_x, PM_{10}, SO_2, CO, VOC	1 × 1 km	Analyse of emission relies (kt/year) for Asia, uncertainty analysis	Inventory	2020	Atmos. Pollut. Res.	[49]
34.	2001-2017	The tropical part of America, Asia and Africa	11- biomass burning in fires	BC, CO, CO_2, NO_x, $PM_{2.5}$, SO_2, NMOC, NH_3	10 × 10 km	Monte Carlo method	Inventory	2020	J. Clean. Prod.	[50]
35.	2000, 2010 and 2014	Finland, Sweden, Denmark, and Norway. Analysis also at local level: Helsinki area, Copenhagen, Oslo and Vasterbotten	2 – small combustion	$PM_{2.5}$	1 × 1 km	Comparison between local, national, and European TNO inventory	The importance of including the local characteristic of the areas.	2021	Atmos. Environ.	[51]
36.	2017	53 Chinese cities on the East	7	BC, CO, NO_x, PM_{10}, $PM_{2.5}$, SO_2, NMVOC, NH_3	4 × 4 km	Analyses of previous scientific articles	Inventory	2020	Environ. Pollut.	[52]
37.	2012	China: Jiangsu,	1,2,34,7,10	NO_X	3 × 3 km	Previous bottom-up inventory and satellite data	Dispersion model CMAQ	2018	Atmos. Environ.	[53]
38.	2016	China: Qingdao City	1,2,34,6,7,8	VOC	2 × 2 km	Analyses of previous scientific articles Monte Carlo method	Inventory	2020	Process Saf Environ Prot	[54]
39.	2006 - 2016	China: Henan	2,7,9,10- manure management, fertilization, biomass burning	NH_3	3 × 3 km	Analyses of previous scientific articles, uncertainty analysis with AuvToolPro|Tool [55] Monte Carlo method measurement of NH_3 in year 2017	Inventory	2018	Atmos. Environ.	[56]
40.	2000 - 2014	Europe	All SNAP sectors	NMVOC, metals, PAH's, dioxins, PCB's	n.a.	Analyses of previous scientific articles, uncertainty analysis	Inventory	2019	Environ. Int.	[57]

It can be note that 1 article was published in year 2022 and 2017, 2 articles in year 2014 and 3 articles in years 2015, 2016 and 2019. 5 articles were from years 2018 and 2019. The majority, 17 articles, were published in year 2020. Most of the articles, 18 altogether, were published in Atmospheric Environment with 4.5 impact factor in year 2021 and 9.2 rated Cite Store[58]. 6 articles were from Atmospheric Pollution Research, 3 articles from Journal of Cleaner Production, whilejournals Atmospheric Chemistry and Physics and Environmental Pollution had 2 articles each. One paper per journal was from Air Quality, Atmosphere & Health, Chemosphere, Environment International, Geoscientific Model Development, Transportation Research Part D: Transport and Environment, Urban Climate and Journal of Environmental Sciences.

Figure 2: Published years (left) and journals (right) of selected articles.

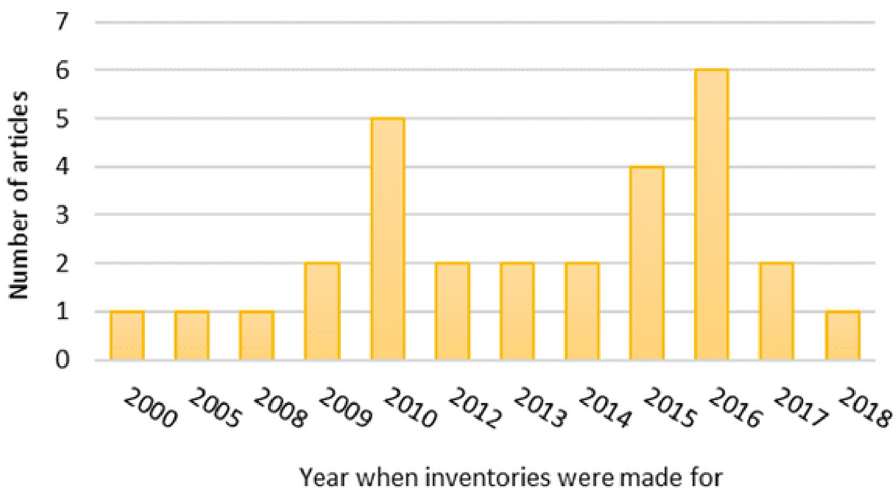




3.1 Period of time

More than half of all inventories (29.) used one-year long time period as shown in figure 3. The most represented years were 2010 and 2016. 8 inventories were prepared for longer time periods, the longest assessed period was 18 years long [40]. One article includes 16 years long period [50] and 2 articles include 14 [41], [57] and 6 years long periods [21], [24]. 1 article each refers to a 10 [56] and 2 year long period [20]. 1 article included only one month, December 2017 [37], besides another article refers on month August in two different years [46].

Figure 3: Distribution of one year long period inventories.



Time lag between the year of inventory and year of paper publication was usually at least 4 years. The highest time lag was 12 years.

3.2 Geographic Area of Inventory

The geographic area of inventories varied from global, national, regional or local scale. Study by Winijkul et. al. [42]included the whole world and collected emission data on the global scale. The same applies to the study by Kuenen et. al. [24], where 51 countries from Europe and North America or countries which reported their emissions under the CLRTAP convention were included [16]. Interesting areas were also discussed in the study by Shi et. al. [50], where main focus was on the tropical area of America, Asia and Africa.
From national point of view, the 14 articles were based on the countries within the Europe, 19 stayed in Chine's region, 7 articles were located in Asia and at least 4 articles include the region within the America. Majority of those were made for cities area, which are the highest sources of anthropogenic emission [59]. The research geographic area depends on the input database accessed [11].

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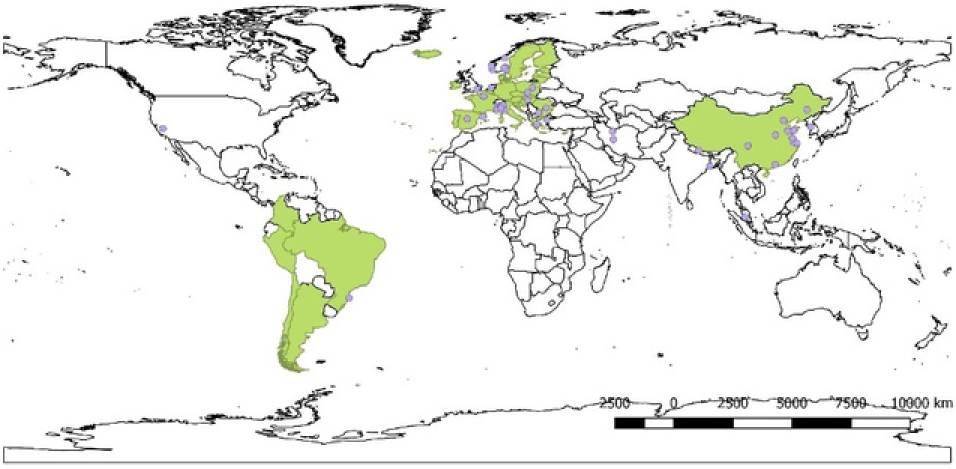
Figure 4: The geographic area of selected articles. Green colours indicate the countries, while purple colours show the cities.



3.3 Including Sectors in the Inventories

9 of all analysed scientific papers covered all SNAP sectors. Extended sectors, but not full SNAP nomenclatures, have been considered in 16 articles. Nevertheless, all of them included SNAP 02 – non-industrial combustion plants or mainly small combustions, 03 – industrial combustion plants and 07 – road transport. Only small combustion sector is involved in 3 studies, while road transport sectors is only included in 5 studies. These two sectors can be found in study by Elessa Etuman et. al [60], while Azhari et. al [38] included road transport sector and small industry. There are two outstanding studies [50] and [41], one focused on biomass burning from fires and another one on burning of crop residual.

3.4 Pollutants included in Inventories

The most common pollutants to be investigated are NOx, SOx and PM10. NOx emissions were included in 25 studies, while SOx was investigated in 20 studies. PM10 emissions can be found in 18 and PM2.5 in 17 studies. CO emissions were researched in 17, NMVOC emissions in 9 studies and NH3 in 10 studies.

The minority of articles, merely in 1 or 2, emissions of O3, dioxins, metals, PAH and PCB were represented, which could be a consequence of less availability and variability of emission factors for certain sectors and technologies [11].

Most studies analyse only one pollutant, but in some cases the precursors of secondary pollutants were investigated, such as VOC [54], [29], [30]. In the study by Z. Zhou et al. [30], where main focus was on VOC emissions, there were 45 VOC profiles and 519 species included, with the purpose of VOC specifications. The aim of the study by E. Winijkul et al. [42] was to analyse size distribution of PM on worldwide scale. In study by A. K. Pathak et al. [35] the toxicity of PM2,5 was researched in the area of Delphi, Greece. On European scale, study by A. Leclerc et al. [57]included the emissions of NMVOC, metals, PAH's, dioxins and PCB's.

3.5 Spatial Resolution of the Inventory

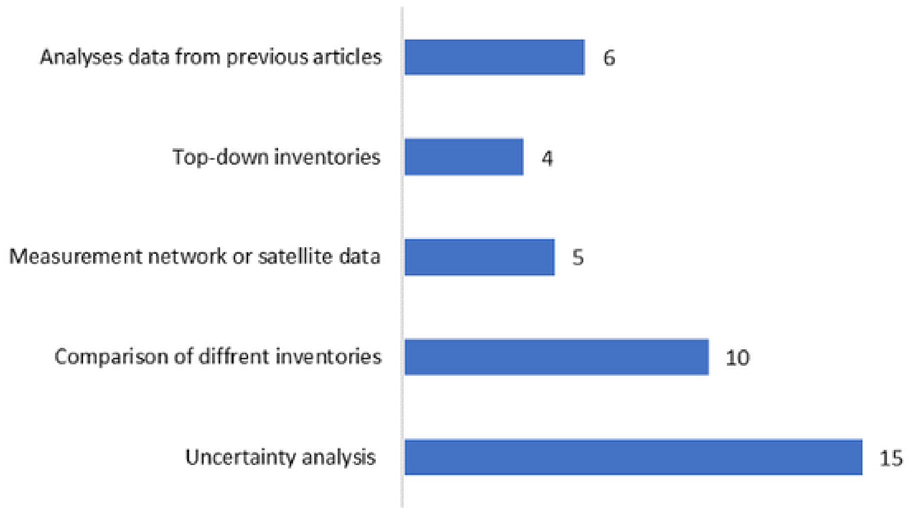
The range of resolution emission's inventories was from 500 × 500 meters [47] to 111 × 111 kilometres or 1° [32]. Majority of them used resolution of 1 ×1 kilometres. Some of the studies have results as common emissions on particulate territories, such as city, municipality, province, or region.

Papers with the main purpose of emission inventory validation, in general did not provide information about the spatial resolution of the inventories, the purpose of those studies was the final result's validation with other methods.

3.6 Validation process and the purpose of inventory

Accuracy of emission inventory is guaranteed through the validation process. Validation can be performed in different ways. In case of previously developed emission inventories, using either top-down or bottom-up principle, for a particular area a comparison between old and new estimated emissions can be done. Even though this approach is a bit rough, it was used in 10 studies [61]. In the case of both bottom-up and top-down inventory availability the comparison with the Diamond graph [62] can be used. This method was developed by The Forum for Air quality Modelling (FAIRMODE), which was lunched under the initiative of the European Environment Agency (EEA) and the European Commission Joint Research Centre (JRC) and is currently chaired by the Joint Research Centre [63]. The Diamond graph recognizes differences between the input data based on the activities and emission factors. This method was used in 4 discussed articles [7], [26], [39] in [13] conducted in European area. 5 of the analysed studies compared emissions based on measurement network or satellite data. The main disadvantage of using satellite data is misleading the secondary emissions, which is the main source of uncertainty [64]. The comparison method was used in 6 papers, either comparison of input data or comparison of new inventories with the results from previous studies. Indispensable was the uncertainty analysis of emission models, based on the description of model uncertainty or with the use of Monte Carlo methods. The last approach was used in 6 studies. Study by Zhang et. al. [56], conducted in China area, used mathematical program tool AuvToolPro [55] to analyse uncertainty as part of validation process.

Figure 5: The validation process used in different studies.



The main goal of the collected studies was to develop validation of emission inventories. In 8 studies the results of emissions inventories were used in air quality models. Comparison of air quality model results with measurement network data still provide some discrepancy. For instance, vehicle emission factors for NOx emissions were typically underestimated, especially during the rush hours [65]. Moreover, emissions of PM can be underestimated due to the disregard of secondary emissions, resuspension and long-range emissions [20]. One of the disadvantage of this validation model is also, that dispersion models more preciously predict the average values of modelled pollution, meanwhile the maximum hourly or daily values are underestimated or overrated [19]. The main focus of five studies was to create different scenarios of fuel use, use of different technologies or changes in activity. In this way, the certain measures to improve local air quality were analysed.

DISCUSSION

Fine spatial resolution emission inventories are useful tools to briefly analyse different emission sources. They can also be used as an input to air quality models. Emission inventory enables to analyse different scenarios for different technologies used and activity changes. Consequently, it represents the effective tool to accept different measurements, which goal is to reach the most appropriate balance between human activities and quality of urban air.

This study found out, that the most covered areas with emission inventories are Europe and China, which could be result of diversity and availability of input data. The need for better spatial resolution, i.e. emission distribution on finer grid, based on the top-down method was shown [13]. The comparison of both methods, bottom-up and top-down, recognized the overrated emissions from top-down methods [66]. The detailed bottom-up emission model is achievable in cases of available detailed input activity and technology data, accessible only in countries or regions with transparent database centres, more common in developed countries [20].

The solution for lack of available activity input data from small combustion and transport on local scale offers the OLYMPUS model [27]. Model considers everyday citizen activities and defines their mobility needs around the city. Sum of each activity represents the common activity in city Paris. The spatial distribution of mobility is based on the proximity of service facilities or private buildings and use of different transport vehicles. The model also considers small combustion based on the energy use of buildings. The main model input data are population density, location of service facilities, road network, public transport and meteorological characteristics that have an impact on emissions [60].

Our study recognized that emission inventories need improvements of source identification and specification in the urban environment. Additionally, there is a need to broader knowledge about the formation of secondary emissions, emissions from resuspension and chemical-physical processes, which could be implemented in the inventory [20].

Furthermore, additional studies focused on discrepancies between bottom-up and top-down emissions on smaller area are needed. A tendency to make inventories with higher spatial resolution is evident [20], [67].

The requirement to acquire more precise emission factors for dominant technologies used in all SNAP sectors in a given area, was shown. More studies are needed with the focus on emission factors related to different conditions. Consequently, it is recommended to fund more studies, which purpose will be research emission factors obtain from different conditions [57], [34].

This study shown that almost all analysed inventories deal with anthropogenic emission sources. The natural emission sources can as well contribute to higher emissions, such as occurrence of desert dust.

Last but not least, the important step in emission inventory development is analysis of model uncertainties and sensitivities. In the most research papers included in our study, the uncertainty analysis and Monte Carlo method was used [13]. In the future, we suggest the improvement in comparison methodology to enable two inventories to be compared for the same area by different parts like sectors, activity use, emission factors, and population density [26]. Currently the Diamond graph is effective tool for comparisons of bottom – up and top – down emission inventories [26].

Above listed improvements will lead to the effective tools for assessment of measures targeting urban air quality.

CONSLUSION

Air quality can be assessed by measurement network composed of representative monitoring sites equipped with certain measurement equipment. On the other hand, air quality models represent reality with uncertainties. Their accuracy also heavily depends on the accuracy of input data. Emission inventories with fine spatial distribution and temporal emissions release are essential for defining effective air-pollution-control measures. They are help finding the compromise between human goods and health environment. Literature review showed there is still deficiency of available good quality input data to analyse sources. Furthermore, emission factors should be researched more, especially for new and widely used technologies. Currently the most covered states are China and Europe. Slovenia still has a lot of space to improve national Emission Inventory based on the bottom-up methods [68].

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