Supplementary Materials

Collection of Definitions

Definitions for diffuse emissions

- "Diffuse sources means the numerous small or distributed sources from which pollutants may be released into soil, air and water, the combined effect of which on those sources is not sufficient to prevent the release of pollutants into the environment media" [65]

- "Diffuse emission refers to pollution infiltrating the atmosphere from a large non—point source, for example, dust from a slag heap" [64]

Definitions for fugitive emissions

- "Fugitive emissions are intentional or unintentional releases of gases from anthropogenic activities. In particular, they may arise from the production, processing, transmission, storage and use of fuels, and include emissions from combustion only where it does not support a productive activity (e.g., flaring of natural gases at oil and gas production facilities)" [66]

- "Emissions not caught by a capture system; which are often due to equipment leaks, evaporative processes and windblown disturbances" [67]

- "Intentional or unintentional release of greenhouse gases may occur during the extraction, processing and delivery of fossil fuels to the point of final use. These are known as fugitive emissions" [27]

- "Fugitive emissions are those emissions which could not reasonably pass through a stack, chimney, vent, or other functionally-equivalent opening" [163]

- "Fugitive emissions consist of all air releases not released through a confined air stream and may include both point and diffuse sources" [69]

- "Fugitive emissions are those emissions entering into the atmosphere that are not released through a stack, vent, duct, pipes, storage tank, or other confined air stream. These emissions include area emissions and equipment leaks" [120]

- "Fugitive emissions occur throughout production facilities and arise from the thousands of valves, pumps, tanks, pressure relief valves, and flanges" [164]

Definitions for point sources

- A point source is "any single identifiable source [...] from which pollutants are discharged, e.g., a pipe, ditch, ship, or factory smokestack" [165] taken from [70]

- "Pollution entering a water body from a discrete conveyance such as a pipe or ditch" [166]

- "The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants

are or may be discharged. This term does not include agricultural stormwater discharges and return flows from irrigated agriculture" [119]

- "A point source is an emission that is fixed and/or uniquely identifiable, such as a stack or vent" [120]

- "Point sources discharge pollutants directly into environmental media (e.g., air or water) from discrete identifiable points where emissions can easily be metered. Sewer pipes or outfalls releasing wastes into streams, or smokestacks discharging plumes into the air are iconic point sources" [167]

- "Sources of particulates are divided into those arising from a single, well-defined emission source, which is called point-source pollution, and those originating from a wide area, which is called nonpoint source pollution" [168]

- "Point sources are emissions that exit stacks and flares and, thus, can be monitored and treated" [164]

- "Point Sources are large, stationary, identifiable sources of emissions that release pollutants into the atmosphere" [71]

- "Within a given point source, there may be several emission points that make up the point source. Emissions point refers to a specific stack, vent, or other discrete point of pollution release. This term should not be confused with point source, which is a regulatory distinction from area and mobile sources. The characterization of point sources into multiple emissions points is useful for allowing more detailed reporting of emissions information" [71]

- "A point source is a stationary, identifiable source of air pollution that usually emits the air pollutants through a stack or vent. Examples of an air pollution facility are steel mills, oil refineries, electric generating facilities, and coal preparation plants. A non-industrial facility may contain a large boiler or other air pollution source" [121]

Definition for non-point sources

- "Nonpoint Source Pollution: Pollution resulting from intermittent discharges of pollutants from diffuse sources and is in transit over land before entering a water body" [166]

- "Nonpoint sources are also referred to as "area" or "diffuse" sources" [72]

- "Non-point sources of pollution are often termed 'diffuse' pollution and refer to those inputs and impacts which occur over a wide area and are not easily attributed to a single source" [70]

- "Pollutants from nonpoint sources move to environmental media by diffuse, and sometimes very complex, pathways. For example, eroded soil carried in storm runoff from farm fields, deforested mountain slopes, or construction sites to streams or lakes" [167]

- "Sources of particulates are divided into those arising from a single, well-defined emission source, which is called point-source pollution, and those originating from a wide area, which is called nonpoint source pollution" [168]

- "Nonpoint sources are fugitive emissions that are difficult to locate and capture" [164]

Definitions for diffuse sources

- "Diffuse sources are not actively ventilated or exhausted. In other words, diffuse emissions that are captured, treated, monitored, and emitted via a stack should be considered a point source, and not included in diffuse sources. Diffuse sources include soils, surface water/evaporation, buildings, tank venting, equipment venting and releases from underground testing" [69]

Definitions for area sources

- "Area sources emit methane somewhat evenly over a large area" [73]

- "Area sources are smaller sources that do not qualify as point sources under the relevant emissions cutoffs. Area sources encompass more widespread sources that may be abundant, but that, individually, release small amounts of a given pollutant. These are sources for which emissions are estimated as a group rather than individually. Examples typically include dry cleaners, residential wood heating, auto body painting, and consumer solvent use. Area sources generally are not required to submit individual emissions estimates" [71]

Definition for confined sources

- "Methane from confined sources, where the gas is physically contained, can be managed with industrial process units" [73]

Definition for unconfined sources

- "We consider anything open to the atmosphere and not captured in the above three categories as an unconfined source" [73]

Detailed Information about the PS/NPS Categorization in Table 4

Methane emissions from the **ocean** are the prime example for an NPS, since methane gets emitted over a wide area. The same is true for **freshwater** emissions. Nevertheless, Walter et al. [122] use the term point sources when discussing ebullition of methane, which results from a very focused viewpoint not applied in this article, when discussing global methane emissions. **Clathrate** emissions can be seen as PS or NPS depending on the viewpoint (Problem **Error! Reference source not found.**): direct methane emissions from a clathrate-fragment may be regarded as PS, whereas emissions from a group of small and distributed clathrate sources (similar to other small sources like animals) may be regarded as NPS. Also, the temporal dimension plays a role here: If the emission is referred to the moment in which gaseous methane leaves the clathrate it is more likely a PS, whereas if the emission refers to the moment when methane reaches the atmosphere after travelling through the water column, the area of emission is drastically higher favoring the term NPS.

Similar to oceans, **wetlands** also emit methane over large areas where individual sources can't be identified. Wetlands are thus defined as NPS.

Methane emissions from natural **biomass burning** arise over large areas and are thus NPS. More debatable are emissions from **wild animals** and **arthropods**, which could be PS if the viewpoint is focused on the individual emitter. Due to the non-stationarity and the low individual emission rate of the of said emitters the term NPS fits better for a global emission assessment.

Another example for a natural NPS is **thawing permafrost**, where large quantities of methane could be emitted in the future [112].

Etiope et al. [11] classified the individual **geological sources** without further elaboration. Still, the authors agree with the proposed PS and NPS classification of the geological point sources because they exhibit a physical containment and display high individual emissions.

N**atural gas and petroleum production proceses industries** as well as **coal mines** are too diverse to be included in the same source type. Besides PS emissions like venting or incomplete combustion when flaring methane which are partly done unintentionally, there are also NPS emissions, for example, microseepage, resulting from gas or oil production or methane emissions from surface coal mines [110].

Stationary combustion processes are per se "stationary" and in general PS, unless sources are numerous and extend over larger areas such as small-scale combustion in households. The same is true for **mobile combustion sources**, where emissions properties are similar to animals and thus are more often NPS than stationary combustion sources. Large ships might be better classified as PS, but again is debatable when considering the global viewpoint.

B**iogas plants** can be characterized as stationary source with fugitive emissions, since methane is the main product and all losses result in a lower output and occur thus unintentionally. Since the methane sources from biogas plants are independent from each other, the definition of a PS fits best.

Emissions from **enteric fermentation** are similar to the already discussed emissions from wild animals, with the difference that mass livestock farming highly limits the area of emission. Research aims at developing models and methods to measure and predict those emissions. In said research ruminants can be seen as individual point sources or as large area sources [129]. Again, the viewpoint is the deciding factor. The areal extension of emissions depends also on whether the livestock is held inside a stable or outside or maybe both. The same argumentation applies for **manure** and the manure management. When uncollected, manure is a clear NPS, but when collected manure emissions fit the PS definition.

Rice paddies as well as **biomass burning** for agricultural purposes are unconfined and emit methane over a wide area without visible emission points and thus meet the NPS definition.

Emissions from **wastewater** originate from PS when emissions from wastewater treatment systems occur [133], but also can stem from NPS when the wastewater emits methane uniformly over large areas when uncollected or even when collected [124]. Therefore, depending on the specific emission of this category, either definition may apply.

Industrial incineration of waste mostly occurs in stationary plants with stacks making them PS. Private waste burning or the incineration of waste on landfills on the other hand would be more attributable as a NPS, since the area is larger, unconfined and the emission is more distributed.

Landfilling is considered by some authors as PS, [126,135], while others consider it as an NPS [124,128,136,169]. Again, the viewpoint is critical. To keep the categorization consistent, a more global viewpoint is chosen and due to the, at least compared to some other PS, rather large areas of landfills, NPS-categorization is preferred.

Industrial methane emissions result from confined and stationary sources and are thus point sources and also mostly fugitive.

The newly proposed category of anthropogenic water-related emissions can also be summed up like the emissions from freshwater and thus fit best under the category NPS.

Additional References

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