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General framework for urban catchment characterisation

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Source Control Options for Reducing Emissions of Priority Pollutants (ScorePP)

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Abstract

In this task we provide a framework for control of PP emissions from urban catchments in European cities. A concept of geographical data organization is proposed, i.e. elaboration of a geographical information system (GIS). In particular, the focus is on the upgrade of the local GIS, by introducing information about priority pollutants (PP) emissions from the urban area. This is performed by linking the urban area GIS to a central database (CDB) of PP emissions, developed within the ScorePP project (Task 9.3). The result is a GIS framework suited for visualization, analyses, and control of PP emissions in urban catchments. Finally, in this conceptualisation all actors, including data providers, modellers, and end users, and their roles are identified and general workflow of data flow and information use is provided.

Acknowledgement

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1. Introduction

Geographical Information Systems (GIS) have widely been applied for the estimation of pollutants loads, identification of critical areas, decision support and siting of treatments (e.g. Palmeri and Trepel, 2002; Nordeidet et al., 2004). Although the majority of GIS application deals with large watersheds (see for example Vink and Peters, 2003), urban scale applications have been implemented for the identification of stormwater pollutant loads (e.g. Ventura and Kim, 1993; Park et al., 2007). GIS is commonly applied for the modelling of non-punctual sources, thus the land usage is the main factor that is considered in the catchment characterization (see for example Ha and Stenstrom, 2003; Park and Stenstrom, 2008).

The utilization of Geographical Information Systems can provide a useful tool in the reduction of Priority Pollutants (PP) sources. In this report we present a framework for characterization of urban (sub)catchment data in order to be applied for analyses and control of PP sources. Such characterisation allows the integration of the geo-referenced information in a GIS relational database for PP control. Moreover, depending on the accuracy of the collected data on PP the system can provide different scale level of information.

Within the ScorePP project detailed information on PPs sources has been collected, which includes general knowledge about the processes in the urban catchments that release PP (e.g. release from households, release from industrial processes, etc.). Putting geographical dimension on the identified PP sources would enable a comprehensive representation of PP sources and their control in specific urban catchments. Furthermore, the development of models for the assessment of PP reduction strategies, which is also part of the project, requires the inclusion of several physical features (e.g. sewer network, treatment facilities, etc.) to enable a full description of the PP behaviour and fate in the urban catchment.
Therefore, the catchment can be characterized by subdividing the main features that can be included in the GIS relational database into three classes

- Areal data: in this category are included all the PP sources which are related to a specific land usage (e.g. parking areas) or a specific cover (e.g. metallic roof);
- Linear data: mainly linear PP sources (i.e. roads) and sewer pipes;
- Punctual data: all the punctual PP sources that have been identified into urban areas (e.g. households, industries, etc.), treatment facilities (e.g. Wastewater Treatment Plants), emission to natural waters (e.g. sewer overflow structures, discharge points).

The goal of this report is to provide guidance on how to organize and specify these data in order to be integrated in a general framework for GIS analyses of the PP emissions. The framework can be used for visualizing, control, and scenarios testing of PP emissions.

2. Characterizing the PP sources

In order to be used in systematic manner (in a multi-objective relational database) the sources of PP need to have a unique classification. Such a classification has been proposed within the Task 9.3 in the ScorePP project. It is a combined classification composed of three codes, i.e. each source of PP emission is uniquely declared by three classification codes:

Table 1: emission strings for Benzene (CAS: 71-43-2)

ES-ID	NACE	NACE description	NOSE-P	NOSE-P description
25	19.1	Manufacture of coke oven products	104.08	Characteristic processes in the manufacture of coke, refined petroleum products and nuclear fuel, involving fuel combustion
502	19.20	Manufacture of refined petroleum products	105.08	Characteristic processes in the manufacture of coke, refined petroleum products and nuclear fuel
64	23.49	Manufacture of other ceramic products	104.01.01	Other furnaces

- CAS registry number: compound or PP number
- NOSE-P: emission process classification
- NACE: economic activity classification

Examples of PP emission sources as they are defined in the Central relational DataBase (CDB) are given in the Table 1 above.

The reader is referred to the Task 9.3 report for more detailed description on these classifications. As stated previously, release processes have been identified within the ScorePP project and classified according to the proposed combined classification. The main purpose of this classification of emission sources is the insertion into a central relational database (CDB), schematically presented in Figure 1, allowing different systematic analyses of the available information. Two basic features are evident. Each emission process is linked to corresponding legislations, meaning that we can analyze the emissions of PP from legal aspect and to emissions models, which means quantification of identified emissions of PP.

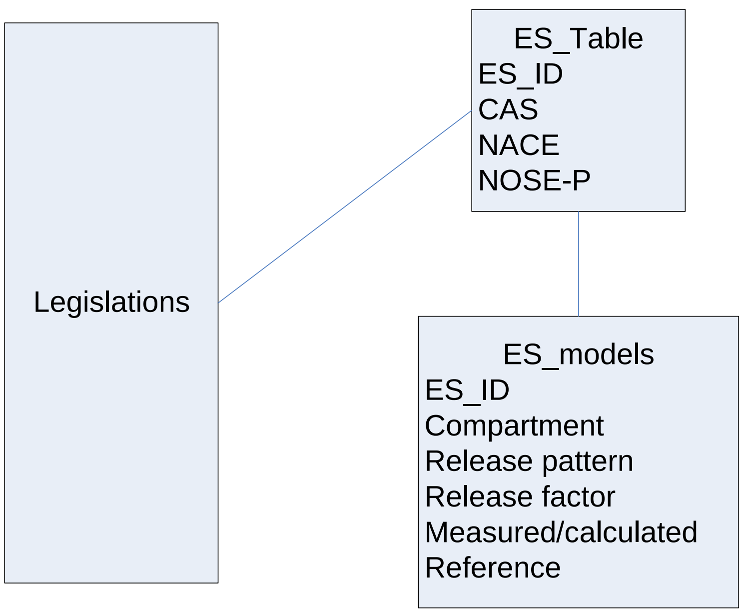

Figure 1: Basic features of data organization in the Central DB of emission sources

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In terms of legislations, for each emission string it is possible to browse through several legislations that are valid for that specific emission. Currently EU Legislation, Swedish, and Slovenian legislation are implemented in the ScorePP database. As for quantification of emissions sources, the following information (generated in Work Package 3 – WP3) can be extracted from the CDB:

- Compartment to which an ES is released and percentage of the emission that contributes to the specified compartment. Following compartments are taken into account: *Air* (A), *Water direct* (WD), *Water indirect* (WI), *Water* (W), *Urban permeable surface* (UP), *Urban impermeable surface* (UI), *Urban surface* (U), *Ground water* (G).
- Release Pattern indicates the dynamics (e.g. weekly, monthly or yearly) of a PP release from specific process.
- Release Factor is a specific value (and corresponding units) of an emission. It is introduced as a range of values, i.e. low and high. Typical examples:
    - g of PP per km of road per car
    - PP released per PP quantity sold
    - Emissions from households, mg PP released / inhabitant
    - PP released per specific process (applied, burnt)
- There is also information on data availability estimate and whether the release factor is measured, estimated, calculated, expert judgment.
- Finally, each ES input has a reference list and comments.

3. Linking ES with geographical data

In order to characterize (prepare) a specific urban area for GIS analyses on PP releases, suitable geographical information needs to be collected i.e. GIS of the area. The minimal requirement for geographical information is presented as a set of shape files, i.e. files that contain geo-positioned elements with suitable set of attributes that describe their characteristics. These files are listed in the Table 2 below.

Table 2: List of shape files and attributes of GIS for analyses on PP releases

SHAPE FILE	ELEMENT TYPE	ATTRIBUTES	COMMENT
CATCHMENT	POLYGONS	ID	Catchment is considered as a contributing area to a single WWTP. If an urban area has three WWTPs, then it is divided into three catchments. Each catchment can be divided into sub-catchments
SUB-CATCHMENT	POLYGONS	ID	
		CATCHMENT_ID	
FACILITIES	POINT	ID	
		NACE	classification of economic activity

SHAPE FILE	ELEMENT TYPE	ATTRIBUTES	COMMENT
		NOSE-P	process classification; if exists
		DISCHARGE TO: SEWER ID, WWTP_ID, WB_ ID...	WB = water body
HOUSEHOLDS	POLYGONS (ROOFS)	No. PE	
		ROOF MATERIAL	Note: if you can not find exact data, please try to provide estimation: e.g. 50m2 of metal roof discharges to specific sewer (if possible with discharge location); or if possible polygons of roof: one polygon has roofs of same type and same discharge location, i.e. same main collector
		AREA	
		DISCHARGE TO: SEWER_ID, WB_ID, ON-SITE TREATMENT	
ROADS	LINES	ID	
		TRAFFIC FREQUENCY	
RUNOFF COLLECTION FACILITIES FROM ROADS	POINTS	ID	
DUMPING GROUNDS	POINTS	ID	
		LEAKAGE LOCATIONS	
		AREA	
SEWERS	LINES	ID	
		TYPE OF SEWER SYSTEM	combined sewer system (CSS) or sanitary sewer system (SSS)
		PIPE'S PROPERTIES	diameter, length, material
		DISCHARGE TO: WWTP-ID, WB_ID	
SEWER OVERFLOWS	POINTS	ID	
WWTP	POINTS	WWTP_ID	
		CATCHMENT ID	
		CAPACITY	

SHAPE FILE	ELEMENT TYPE	ATTRIBUTES	COMMENT
		TYPE OF TREATMENT	activated sludge, biofilters, stage of treatment (ii or iii)
		DISCHARGE TO: WB_ID	
RIVERS	LINES	RIVER_ID	
		FLOW RATE (AVERAGE)	
		TRAFFIC	YES, NO (existing traffic or not)
OTHER WATER BODIES	POLYGONS	ID	
		TRAFFIC	YES, NO (existing traffic or not)
GREEN AREA	POLYGONS	ID	
		TYPE	gardens, parks, forest...
		AREA	
PARKING LOTS	POLYGONS	ID	
		AREA	
RAIL ROADS	LINES	ID	
GAS PIPELINES	LINES		
OTHER SPECIFIC AREAS			examples: airports, mines, historic pollution of sediments and soil

After the collection of these basic data, the GIS needs to be upgraded with information on PP sources in the study area. Here we establish a link with the CDB. This link is presented in Figure 2. Thus, putting geographical information on the existing identified PP emissions results in a solid GIS which would fulfill the goals of the ScorePP project, i.e.:

- Calculating emissions from specific areas
- Visualizing (geographically) PP sources
- Controlling PP sources
- Performing treatment and control scenarios

In short, such a framework is sufficient for decision support system on PP control and reduction.

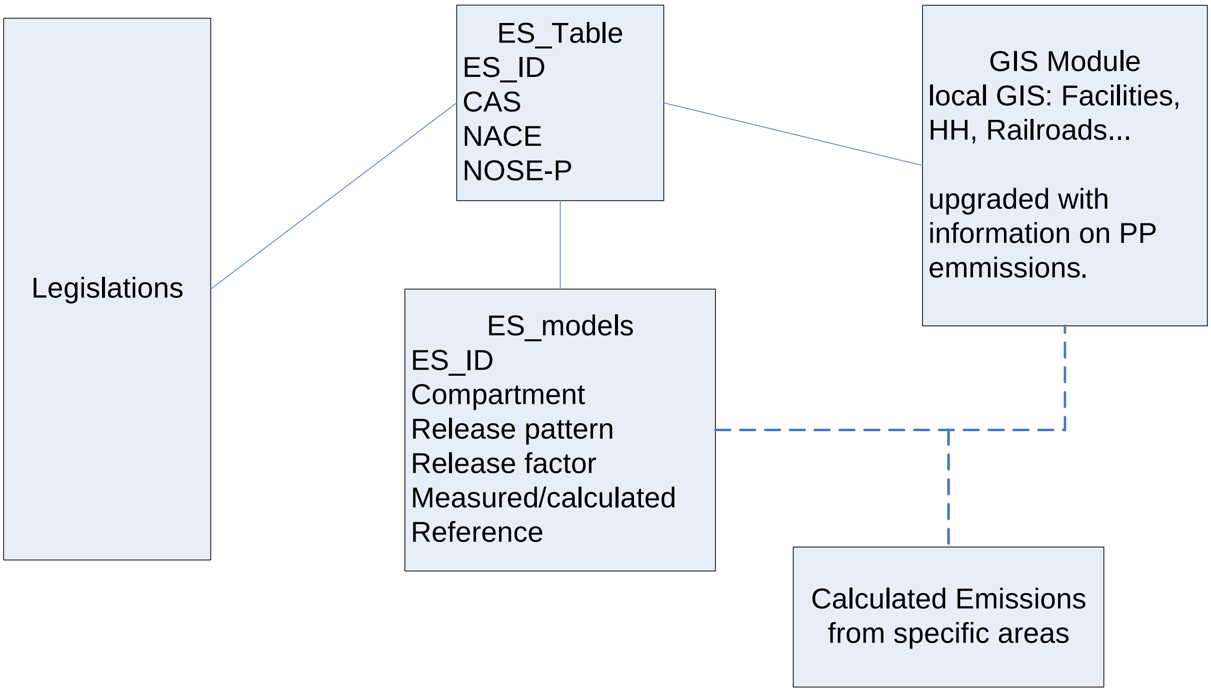

Figure 2: Upgraded CDB with a link to the GIS module

Given that a local GIS of a specific urban catchment including the information from Table 2 exists, the preparation of the catchment for the inclusion in a PP control framework will pursue the following points:

1. Identifying releases of PP (or ES) in the urban area under consideration.
2. Reviewing existing ES in the CDB and selecting those which apply to the urban area under consideration. Note here that by selecting an ES from the CDB we also get information on ES quantities as described above (e.g. release low, release high…).
3. If a release process (ES) does not exists in the CDB, a new ES must be introduced, by specifying all data required in the CDB (CAS, NACE, NOSE, and so on).
4. Introduce location (coordinates) of the identified ES and type of ES
5. Quantification of the emission. Here we expect more detailed information than what already exists in the CDB, since the location of the emission is known. Note that the data in the CDB are general and mostly taken from literature. Therefore, 'case cities' provide more detailed information about the urban area under consideration.
6. Introduce the emission pattern, i.e. pattern of daily, weekly and yearly release, if data are available.

In the Table 3 below we provide a template for collecting emission data from an urban catchment.

For an easier implementation of the geographical data into the CDB the data providers should take into account two considerations. The first one is a consistent insertion of *Release factors*, so that all emissions are expressed in one unit, (e.g. kg/year). The second one relates to data sensitivity. As most of the emission data are not publicly available (this applies especially to emissions from industries), the detailed locations (coordinates) of the emissions will be omitted and geographically presented only with the catchment ID. This should avoid possible conflicts and preserve the information collected during the project.

Table 3: Template for collecting emissions data from an urban catchment

Column	Comment
ES ID	
LOCATION ID	e.g. Facility_ID, Road_ID
Shape file name	
LOCATION (X, Y)	if the location is already in the shape files (facility) then this info is not needed here. Only if the location of this emission is not already in the shape files.
(SUB)CATCHMENT_ID	
DISCHARGE TO	WWTP_ID, WB_ID...
Percentage estimate	Release percentage to suitable Compartment, e.g. 100% to water
Compartment	Air (A), Water direct (WD), Water indirect (WI), Water (W), Urban permeable surface (UP), Urban impermeable surface (UI), Urban surface (U), Ground water (G)
Release Pattern	pattern of daily, weekly, and yearly release
Parameter values	
Release factor low	these three values represent the range of the release factors
Release factor high	
Release	
Release factor units	
Data availability estimate (1 high, 2 medium, 3 low)	
Source of the release factor: Measured (M), Estimated (E), Calculated (C), Expert judgment (EJ),	
Reference IDs	
Comment	

It is very important to note here that sources of emissions with no data must also be added (but without yearly loads). The same is valid for potential emission sources.

In order to have an effective decision support system modelling is of key importance. Including models in this framework would enable performing different scenarios of treatment and reduction options for PP. Note here that models of the fate of PP are developed within the ScorePP project (WP7). The models are dynamic and as such difficult to include in the GIS framework. However, the information gained from the modelling task will be included in the GIS in a simpler manner, e.g. as steady-state model, and enable performing scenarios. Note also that the models developed in ScorePP need geographical information as well.

So, a link (interaction) between CDB, geographical data providers (hereafter defined as Case Cities), and Modellers should be established. Generally, Case Cities provide information to Modellers and CDB. Subsequently, modellers provide their results to CDB. The final result is the GIS, as decision support system. In the Figure 3 below we present the workflow of data to be used for modelling and further analyses within the SCOREPP project.

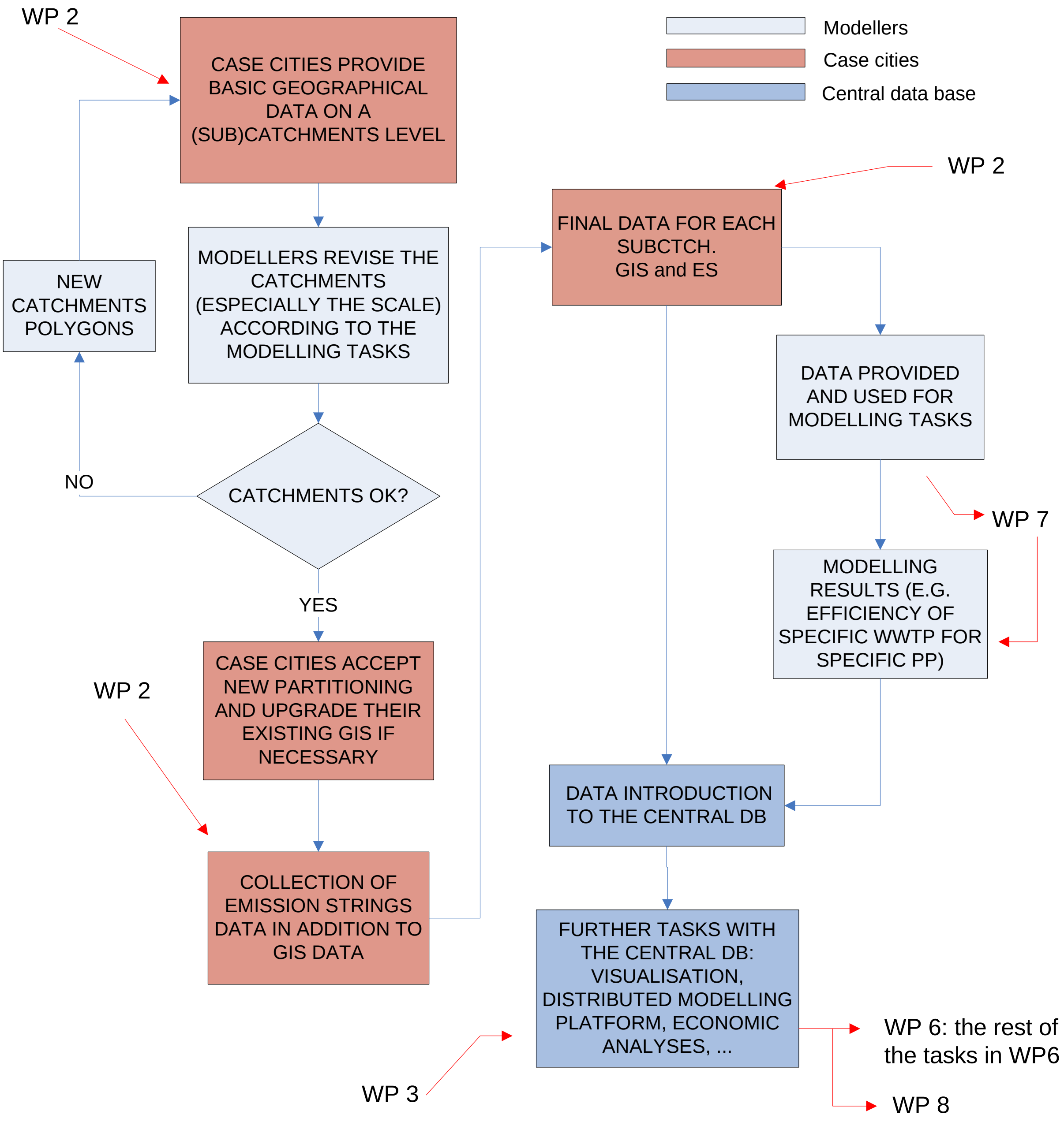

Figure 3: Work-flow for preparing and organizing data into a GIS. Different colors denote the actors involved in specific action as stated in the legend. The data flow is put in the context of SCOREPP work packages, i.e. red arrows indicate the origin and the final use of information

Case Cities and modellers define the final partitioning of the urban catchments into smaller sub-catchments according to the modelling tasks in the project. This is done based on spatial data exchange in a form of shape files (Table 2). According to the final partitioning of the urban catchment, which is approved by both modellers and Case Cities, Case Cities upgrade their local GIS and provide further information on this sub-catchments level, as described above.

4. Data organization from users perspective in the ScorePP project

In the ScorePP framework, two main information users have been identified, with different types of data requirements. Therefore we foresee the elaboration of two types of GIS databases, which differ in data resolution, i.e. the data collected have different scale of integration:

1. The local GIS represent an upgrade of the existing GIS of the case cities involved in the project. Currently the GIS includes geographical information about the (sub)catchments within a case city and corresponding infrastructure data, such as sewer system, roads, WWTP, etc.. This information is shared with the modellers in terms of shape files. Using the information from other tasks in SCOREPP project (e.g. Task 3.2) the existing GIS will be upgraded with data on PP emissions.
2. The Central Data Base (CDB) is focused on data related to PP emissions. This information is linked with the elaborated GIS on a local level, which results in a complete GIS for control of PP emissions. Further, the CDB is designed in a way that enables different scales of visualisation, from detailed (if such data is available) to more integrated. The later is performed by aggregation of the collected data to points, i.e. to pre-defined (sub)catchments. The level of partitioning to sub(catchments) is determined by the users, e.g. modellers, since it has to be sufficient for the modelling tasks. For example, information on pollutant loads from diffuse sources (roads) will be presented in the DB as point sources, i.e. they will be aggregated to one point, representing the catchment of origin. Such aggregation is suitable for spatial analysis on a larger scale, e.g. entire cities, countries, and also at EU level, and if the partitioning is detailed enough also for detailed modelling on smaller scale.

5. Conclusion

In this report we provide a conceptualisation of an urban catchment data to be used in a GIS for control of PP emissions. It is based on the elaboration of a local GIS, which is then linked to a central database on PP emissions. The link is used for upgrading the existing GIS with information on PP emissions. Proposed framework is detailed enough for urban catchments modelling tasks and, at the same time, general enough to be used for distributed (spatial) modelling at larger scale. It can be used for visualizing (geographically) PP sources, controlling PP sources, and performing treatment and control scenarios in the catchment. Future work will focus on the implementation of this framework on the case cities within the ScorePP project.

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