

Copenhagen: Rainwater quality and handling of urban run-off

Copenhague : qualité des eaux pluviales et maîtrise des rejets urbains de temps de pluie

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RÉSUMÉ

Copenhague est actuellement en train de mettre en œuvre un programme de prévention contre les inondations de plus d'un milliard d'euros, afin de protéger la ville lors de pluies torrentielles. Le réseau de tunnels, de canaux, de zones vertes ainsi que plusieurs plans d'eau facilitent la déconnexion des eaux de ruissellement du réseau d'égout offrant une alternative plus économique à l'augmentation de la capacité hydraulique du système d'égout actuelle. En se basant sur des analyses des eaux de ruissellement provenant de toits, de cours, de places et de rues, la qualité de l'eau de chaque surface urbaine est caractérisée. La qualité de l'eau de ruissellement provenant d'une zone urbaine composée de différents types de surfaces peut ainsi être estimée. Cette qualité de l'eau est comparée à la qualité des eaux réceptrices grâce à une évaluation des risques. Si les critères de rejet ne sont pas remplis, le choix est soit de mettre en place un traitement des eaux, soit d'empêcher les ruissellements les plus pollués (provenant par exemple des rues à forte circulation) en les évacuant dans le réseau d'égout. L'article propose une méthode de calcul de la qualité de l'eau de ruissellement d'une zone urbaine, la mise à disposition des données et identifie les éléments critiques dans les types de surfaces sélectionnées. De plus, des recommandations sont faites pour améliorer la qualité des données et la prise de décision dans la gestion des eaux de ruissellement urbaines.

ABSTRACT

Copenhagen is presently implementing an over one bill. EUR flood protection program to protect the city against cloud burst. The system of tunnels, canals, green areas and various water bodies facilitates disconnection of the urban run-off from the combined sewer as a cheaper alternative to increasing the hydraulic capacity of the existing sewer. Based on analyses of run-off from roofs, yards, squares and streets, the typical water quality of run-off from each type of urban surface is characterized. The resulting water quality of run-off from an urban area consisting of various types of surfaces can thus be estimated. This water quality is compared with the sensitivity of the receiving water using risk assessment. If discharge requirement are not met, the choice is either to introduce treatment or to avoid run off from the most polluted areas by continued discharging to the sewer (i.e. streets with heavy traffic). The paper proposes a method to calculate the water quality of run-off from an urban area, the availability of data and identifies critical compounds in the selected surface types. Further, recommendations are given on how to improve data quality and to improve decision making in handling of urban run-off.

KEYWORDS

Urban surface types, Urban run-off, water quality

1 INTRODUCTION

1.1 Background

Copenhagen is presently implementing an over one bill. EUR flood protection program to protect the city against cloud burst. The program also includes the necessity to disconnect 30% of the areas connected to the combined sewers, to compensate the fact that it presently is estimated that the rainfall intensity in DK will increase by 30%. A system of tunnels, canals, green areas and various water bodies will facilitate disconnection of the urban run-off from the combined sewer as it is a far cheaper alternative to increasing the hydraulic capacity of the existing sewer.

However, there is a need for a better estimation of the quality of the disconnected run-off to minimize the potential impact on receiving water bodies. The most important environmental regulation for water bodies include:

- The EU water framework directive implemented in National law (The Danish Water Management Plans)

The EU water framework directive is in Denmark implemented in national water plans. In these management plans many water bodies shall meet the requirement in the form of good ecological and good chemical quality no later than in 2027. While working with climate adaption and the aim to increase discharge of run-off to the recipients, it is important to focus on the water quality of the run-off to maintain the goals of both the ecological and chemical quality in the water management plans. To make sure of this, the developed screening tool is used to assess if negative impacts on the water bodies are supposed to take place.

- Bathing water

Copenhagen municipality wishes to maintain bathing water quality and continuously improve the ecological and chemical conditions in the harbour. Bathing water requires that discharge of E coli and enterococci from CSO's are reduced, which is followed by a decrease of impacts from other pollutants

1.2 Objective

The water quality of a separate rain water discharge is determined by the materials used in the different urban surfaces (streets, roofs, square, etc.) and the activities on these surfaces (traffic, street cafés, etc.). A screening tool is therefore developed to assist environmental authorities in evaluation of potential environmental impacts from discharge of disconnected run-off. Gaining knowledge about the water quality of the run-off can also help the utility in finding more efficient ways of managing stormwater.

The objectives of developing the screening tool were more specific:

- To collect data on run-off quality from city surfaces like streets, roofs and squares during daily rain
- To identify the most environmentally critical compounds
- To identify the most critical surface types in a run-off catchment
- To develop a method for screening of environmental risks from surface run-off which is discharged to a water body

This paper describes the approach to developing the screening tool and how it can be applied in the work of making cities with combined sewer systems more climate proof by disconnection of run-off from roofs and other areas.

2 METHOD

2.1 Types of urban surfaces

When dividing the city surface into categories the recommendations in the standard developed by the German Association for Water, Wastewater and Waste has inspired to the following divisions into surface types:

1. Inner yards and playgrounds
2. Roofs with copper
3. Roofs with zinc
4. Other roofs
5. Streets with less than 5.000 vehicles/day
6. Streets with 5.000-15.000 vehicles/day
7. Streets with traffic more than 15.000 vehicles/day
8. Parking lots for more than 80 cars

The environmental authorities in Copenhagen has chosen to discharge road runoff to the sewer when the dally traffic exceed 5000 AADT.

2.2 Choice of parameters

Based on literature reviews, collected run-off quality data in Denmark (DK) and internationally and requirements in Danish environmental regulation, 30 indicators are included in the tool. These consist of common wastewater parameters like BOD and COD, nutrients like Tot-P and Tot-N, heavy metals, PAH, phthalates and pesticides.

To assess if discharge of urban runoff might have negative environmental impact on the water quality in the water body it is relevant to compare the PNEC (predicted no effect concentration) for pollutants with the current concentration in urban runoff. If the concentration of pollutants are lower than PNEC in discharged water after initial dilution the urban runoff is not expected to have negative environmental effects

Because introduction of new building materials and change in pollution from cars (e.g. no lead in fuel, copper in brakes, less oil leakage) it was decided only to include data from year 2000 and onwards.

2.3 Calculating the water quality at a discharge point

Based on analyses of run-off from roofs, yards, squares and streets, the typical water quality of run-off from each type of urban surface is characterized and the water quality at a discharge point is calculated by multiplying the size of each area type by the concentration of each compound and the sum it all up :

$$\text{Conc}_{xyz} = ((\text{Area}_x/\text{Area}_{\text{Total}})*\text{Conc}_x)+((\text{Area}_y/\text{Area}_{\text{Total}})*\text{Conc}_y)+((\text{Area}_z/\text{Area}_{\text{Total}})*\text{Conc}_z)$$

Area_{xyz} : The impermeable area (red. ha) of surface type X, Y and Z

$\text{Area}_{\text{Total}}$: The total area, i.e. the sum of Area_x , Area_y og Area_z

Conc_{xyz} : The concentration of a compound in surface type X, Y and Z

The resulting water quality of run-off from an urban area consisting of various types of surfaces can thus be estimated. This water quality is compared with the sensitivity of the receiving water using risk assessment. If discharge requirement are not met, the choice is either to introduce treatment or to avoid discharge of the most polluted areas (i.e. streets with heavy traffic).

3 RESULTS AND DISCUSSION

3.1 Availability of data

There is plenty of data on roof water and some on street water, whereas there is no data on inner squares, pedestrian pavement and inner yards. The following table shows the availability of data where red means: no reportings, orange: less than 5 and green more than 5 reportings.

Table 1. Number of reported data of water quality

	Roofs of copper, copper gutter etc.	Roof of zinc, zinc gutter etc.	Roofs of other materials	Roads (AADT < 5,000)	Roads (AADT 5,000-15,000)	Roads (AADT > 15,000)	Parking lots
Wastewater parameters	12-16	12-19	12-16	4-8	3-4	0-10	0-6
Total-N and Total-P	15-19	15-20	15-19	8	3-4	10-11	0-6
Metals total	2-20	2-20	15-20	4-8	4	13	6
Metals dissolved	0-1	3-4	1	4-8	4	0	6
PAH	15-18	15-22	15-18	8	3	0	2
DEHP	0	0	0	5	3	9	2
Other phthalates	0	0	0	0	0	0-9	0
Bisphenol A	0	0	0	5	3	0	2
Pesticides	0	0	0	0	0	0	0

The majority of the water quality reporting is from DHI investigations in Denmark.

3.2 Critical compounds

3.2.1 Roof water

The main problem with roof water in DK is the widely use of zinc for roofing pans, flashing at windows and gutters. To a lesser extent, copper used on older buildings is similarly problematic. Zinc and copper are environmental toxic compounds that accumulate in the food chain and hamper the biomass.

PAH can also appear in roof water when asphalt roofing is used. Roofs with trees overhanging and/or birds, as well as atmospheric deposition can lead to elevated levels of nutrients in the water.

3.2.2 Street water

The quality of street water depends partly on traffic intensity. Over time the most dramatic change has been observed in compounds originating from the exhaust (earlier it contained lead), from engines (less oil spill today), the brakes and from various car care products. The brakes earlier contained asbestos, but now contains significant amount of copper. PAH in street water originate from the tyres and the asphalt surface, especially during acceleration and braking.

Overview of critical compounds for selected surface types. For each type of recipient the recommended dilution factor included in evaluating impact is shown.

Table 2. Critical compounds for selected surface types

Surface	Marine waters (Dilution 10x)	Fresh waters (Dilution 2 x)	Groundwater (No dilution)
Roofs (other materials than copper and zinc)		Cu	Zn, DEHP, glyphosat
Zinc roofs	Zn, Pb	Zn, Cu, Pb,	Zn, glyphosat
Roads < 5,000 AADT	PAH, bisphenol A	Cu, PAH, DEHP, bisphenol A	Pb, PAH, DEHP, glyphosat
Roads 5-15,000 AADT	PAH, bisphenol A	Zn, Cu, PAH, bisphenol A	Zn, Cu, Pb, PAH, DEHP, glyphosat
Parking lots	Cu, PAH, bisphenol A	Zn, Cu, PAH, DEHP, bisphenol A	Zn, Pb, PAH, DEHP, glyphosat

In relation to improvement of water quality in lakes and achieving good ecological conditions, phosphorous is the most critical parameter. Therefore the load of phosphorous coming from urban runoff is an important parameter to control. Generally roof water and street water contain Total-P at intervals of 0.1-0.3 mg/l and Total-N of 2-3 mg/l.)

Table 3. Concentrations of Total-P, Total-N and BOD for selected surface types (75% percentile)

Surface	Total-P (mg/l)	Total-N (mg/l)	BOD (mg/l)
Roofs (other materials than copper and zinc)	0.11	2.2	-
Zinc roofs	0.26	-	12
Roads < 5,000 AADT	0.13	2.4	3.7
Roads 5-15,000 AADT	1.1	4.6	12
Parking lots	0.24	2.8	-

4 CONCLUSION

4.1 Screening tool

It was found possible to develop a screening tool which is useful for storm water planners and environmental authorities in deciding how separated run-off water is handled with the best possible protection of the receiving waters. The project team identified areas where further data shall be collected to strengthen the tool and identified more clearly which surface materials and urban activities influence the content of critical compounds in run-off water.

Therefore, intensified data collection will take place over the coming years especially focussing on street run-off water from streets, squares and inner yards.

4.2 Need for data collection

4.2.1 Surface types

There is an obvious need for data on run-off water from non-motorized areas like squares, pavement and court yards. The water quality from these areas appears to be in close compliance with the environmental criteria for the three types of recipients (inland waters, other waters and groundwater). Analysis of run-off water from local streets with low traffic intensity shows low concentrations of critical compounds, whereas the level of critical traffic intensity where minimal treatment is sufficient needs to

be identified.

4.2.2 Critical compounds

There are very few data on dissolved metals (Zn, Cu, Pb) in run-off water. The environmental quality parameters for Zn, Cu, Pb in fresh and marine waters are expressed as dissolved metals. Therefore, it is recommended to include dissolved metals in future data collection programs.

For all surface types, data on eco toxic compounds like phthalates, bisphenol A and pesticides as well as for total ammonium (total NH_x-N) and free ammonia (free NH₃-) are virtually non-existent. The need for including these parameters must be clarified as they are important environmental quality parameters.

4.3 Surface materials

When developing new urban areas in Copenhagen regulation on roofing material has been introduced the last 10 years in DK. Materials of zinc, copper and tar-products have been banned, unless it is sealed and it is documented that the run-off contains only low levels of critical compounds.

Widening this regulation to also including renovation of existing buildings could in time lead to gradual decrease in content of critical compounds in run-off.

4.4 Traffic

As it appears today, communication between car manufactures and water environmental authorities does not exist. To minimize the produced street waste from cars, the authors therefore urge car manufactures to focus on exhaust emissions and the materials used both in and on the cars, which is critical to the city water bodies.

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