New guideline for urban wet-weather management in Switzerland

Nouvelle directive pour la gestion des rejets urbains en temps de pluie en Suisse

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RESUME

La mise en place de solutions techniques permettant de limiter les impacts des rejets pluviaux urbains est traditionnellement basée sur une approche de type émission (end-of-pipe). Ce type d'approche n'est plus compatible avec la législation Suisse, pour laquelle le milieu récepteur représente le point de départ de toute réalisation technique. En conséquence, une nouvelle directive, mettant en parallèle les rejets pluviaux et leurs impacts potentiels a été définie. Elle fixe également de nouveaux critères de qualité des eaux qui prennent en compte la dynamique des polluants. Les incertitudes associées aux données utilisées de même que la variabilité des processus sont également intégrés dans une approche probabiliste. Ces changements radicaux de stratégie nécessitent un effort accru de communication entre les différents partenaires.

ABSTRACT

Technical solutions to limit the impacts of the urban wet-weather discharges are traditionally based on end-of-pipe approach. However, nowadays, this type of approach is no longer compatible with the Swiss regulations, for which the receiving water represents the starting point for any technical realization. Thus, new guidelines, linking wet-weather discharges and their potential impacts have been defined. New quality standards which take into account the dynamics of the pollutants are proposed. The uncertainties associated with the necessary data as well as the variability of the processes were also integrated in a probabilistic approach. Such drastic changes of strategy do require an increasing effort of communication between the various partners.

KEYWORDS

Immission strategy, probabilistic approach, time-dependant water quality criteria, urban wet-weather discharges.

1 INTRODUCTION

Urban wet-weather discharges are known as being an important source of detrimental effects on receiving waters. The main problem is to link wet-weather discharges and environmental impairment. Different approaches have been defined worldwide to limit their impacts (see eg. EPA 1995, WEF 1997, EU WRRL 2000, ATV-DVWK 2003). The simplest approach is based on end-of-pipe or emission strategy that conducts to the construction of technical systems (CSO tanks, BMPs…) to achieve pre-defined maximal concentrations or loads for a given watershed. Such an emission approach, with simple focus on the receiving water, has also been used in Switzerland for many years (OFPE 1977). This approach is outdated and does no longer comply with today's urban drainage strategy. In fact, Swiss regulations on water protection requires that receiving water impact be "immission" based, not emission based (LEaux 1991, OEaux 1998). This implies that planning procedures must first consider the state of the aquatic environment and ecosystems and, in case of impairment, the cause-effect relationship between urban storm drainage and the resulting impacts. Thus, a new conceptual planning strategy has been developed in accordance with both the Swiss regulations water protection (LEaux, 1991) and the Swiss master plan of urban drainage (VSA, 1989). This approach is in direct line with the international trends, where the focus increasingly tends towards integrated modelling, taking into account the multi-directional interaction of the sewage system with treatment infrastructure, rivers and groundwater in the receiving waters basin. The integration of various disciplines (i.e. water quantity, quality, ecology, economy, socio-participation) becomes thus more emphasized.

The new guidelines were elaborated within the STORM project that covers the following objectives: 1) definition of wet weather water quality standards, 2) development of a new procedure for planning protection measures 3) development of a software tool to support the planning process, and 4) publication of new guidelines. The aim of this paper is to present the guidelines and the difficulties encountered in promoting its acceptance. In fact, this new approach represents a real revolution in the management of urban wet-weather discharges in Switzerland.

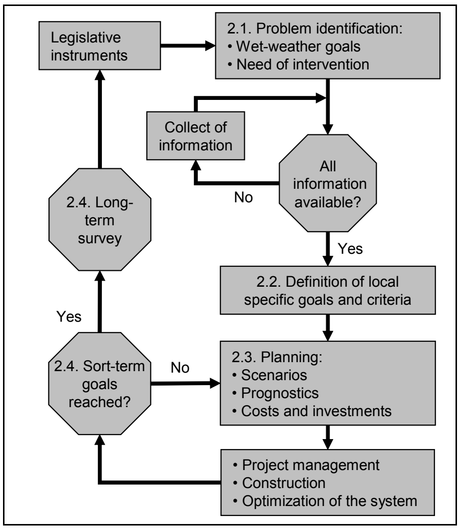

Figure 1: Methodology of the new Swiss guidelines for wet-weather discharges. The numbers in the different cases refer to the chapters in the text.

2 METHODOLOGY

The methodology of the new guidelines is shown in Figure 1. Different steps are discussed within this paper: the preliminary identification of a problem, the definition of criteria, a planning approach with dedicated software, the realisation of constructive solutions, and the survey of such realisations on short and long terms.

2.1 Problem identification

A preliminary matrix to evaluate the main classical wet-weather problems encountered has been elaborated (Table 1) in order to help planners and decision-makers to focus on local specific problems. This table has been established on the basis of recorded problems and literature information linked with wet-weather discharges in Switzerland and in nearby European countries. An important point, however, is to consider local hydrological conditions of the receiving waters. Different classes of receiving waters (small or big rivers, lake…) have been defined with numerical characteristics (not given here) in accordance with other Swiss regulations tools (VSA 2002).

Type of receiving water	Wet-weather problems in receiving waters linked with urban discharges, frequencies (0, +, ++, +++) and domain concerned by the defined criteria (grey areas)												
	Ammonia toxicity	Total suspended solids (TSS)				Dissolved oxygen	Nutrients	Hydraulic stress	Temperature	Hygiene	General aspects		Other
		Water Column	Colmation	Accumulation of toxic substances	Anaerobic conditions					Swimming activities	Coarse matter	Other	
Source region	++	++	++	++	++	+	0	++	++	0	+	++	?
Small lowland river	++	++	++	++	++	+	0	++	+	++	++	++	?
Small pre-alpine river	+	++	0	0	0	0	0	++	+	++	+	++	?
Big lowland river	+	++	++	++	++	+	0	+	0	++	++	++	?
Big pre-alpine river	+	++	++	0	0	0	0	+	0	++	++	++	?
Big rivers	0	0	0	0	0	0	0	0	0	+++	++	+	?
Small lake	0	0	0	0	0	0	0	0	0	+	++	++	?
Big lake	0	0	+++	0	0	0	++	0	0	+	+	+	?
Impounded water	0	0	++	0	0	0	+	0	0	++	+	+	?

Table 1: Pre-evaluation matrix for the assessment of wet-weather impacts

2.2 Definition of wet-weather criteria

Different criteria were selected in the new guidelines and are listed below. These criteria have been adapted from other regulations on wet-weather discharges (EPA 1995, FWR 1998, EU WRRL 2000) or have been determined for specific domains (VSA 1998, Rauch et al. 2002, Rossi et al. 2004a, Kreikenbaum et al. 2004, Rossi et al. 2005a). Such criteria give indicative values instead of regulatory ones. However, they correspond to the general objectives of the current regulations. For some criteria (ammonia toxicity, temperature, total suspended solids), we proposed time-dependent water quality criteria in order to deal with highly dynamic pollution resulting from wet-weather discharges (Chèvre et al., submitted).

- *Amenity use*: This criterion defines the tolerable frequency of visual degradations in receiving water (i.e. presence of coarse material after CSO spills) and is based on an emission criterion;

- *Hydraulic stress in the receiving water:* This criterion fixes a given number of rain events per year that can exceed a hydraulic stress factor in order to protect the receiving waters against too frequent drifts or erosion events. The criterion is function of the characteristics of the receiving water (eco-morphology, type of riverbed…) (Krejci et al., 2004a);
- *Temperature*: Three temperature criteria are defined to protect fish populations in the receiving waters: maximal temperature during summer months, maximal temperature increase during rain events as well as maximal temperature during winter months. A time-dependant criterion is also defined for maximal temperature increase. The assessment of temperature effects is performed with a specific procedure (Rossi and Hari, 2004b);
- *Bacteriological impacts:* The risk of bacterial contamination in the receiving waters, where swimming or bathing activities are expected, is also assessed with a specific procedure (Kreikenbaum et al. 2004);
- *Ammonia toxicity:* This criterion allows long term protection of fish populations by defining limited toxic events frequency in the receiving waters (Rauch et al. 2002). A time-dependant criterion is defined;
- *Total suspended solids (TSS)*: TSS is considered as a tracer for the major pollutants in wet-weather discharges (heavy metals, PAHs…) (Rossi et al. 2005b). A time-dependant curve for TSS is proposed in the water column (turbidity and effects of adsorbed compounds) (Rossi et al. 2005a). The dynamics of TSS deposition-erosion is considered for the riverbed. In this case, three criteria (colmation of the riverbed, accumulation of toxic substances and accumulation of organic substances that can generate anoxic conditions) (Rossi et al. 2004a) are taken into account. For riverbeds, TSS volume accumulation threshold and the duration of TSS accumulation on the riverbed are used as criteria;
- *Nutrients:* Instead of fix criterion, a nutrient mass balance between the different inputs in the watershed of the receiving water is established.

2.3 Planning

The planning procedure proposed in the guidelines offers a probabilistic approach for planning wet-weather water protection measures based on the impact of the received water. Several reasons justified such approach. First, precipitation as the main driving force of the system has stochastic features, which must be taken into account. Moreover, some variables and parameters of the system are difficult to measure (e.g. riverbed characteristics) and so cannot be determined exactly. And finally, the cause-effect relationship between urban stormwater discharges and the receiving water ecosystem, i.e. the criteria defined previously, is hard to describe with a linear relationship. Probabilistic approach requires specific modelling tools while probabilistic models take the variability of the stress factor (rain) into account and include a description of the uncertainties in parameters. In this kind of models, the probability of excess in criteria is represented by a probability function rather than by an exact value. For the planning of wet-weather solutions, the existing REBEKA software (Rauch et al. 2002) was extended with probabilistic modelling facilities and with a Monte Carlo simulation routine (Kreikenbaum et al. 2002). A sensitivity analysis has also been integrated in order to focus the data acquisition on the most important parameters (Fankhauser et al. 2004). Long-term simulations (10 year duration) are performed on the basis of historical rain data from five different locations in Switzerland. The computation typically runs 200 iterations, within most variables and parameters uncertainties are taken into consideration by generating random values of a given multivariate distribution. The results, after sorting, can be plotted as a cumulative distribution function which represents the probability (on the Y-axis) complying with a criterion (on the X-axis). An example of such results is illustrated in Figure 2, where different scenarios (infiltration of storm water, different detention volumes, etc.) can be compared with the actual situation (Kreikenbaum et al. 2002).

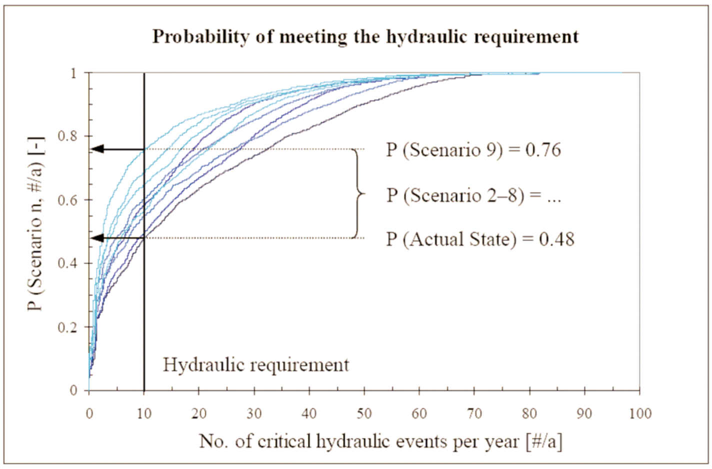

Figure 2: Example of result of probabilistic design (from Kreikenbaum et al. 2002). The different curves represents the probability (Y-axis) of complying with the hydraulic requirements (X-axis) for a specific location (in this case ten critical hydraulic events per year), for different scenarios.

In this particular case, the probability of compliance is only of 48 % for the actual state and of 76 % for Scenario 9. This means that we have a probability of about 50% to reach our criteria (10 critical hydraulic events per year) in the present situation, taking into account the variability of rain over a long period of time (10 years) and the uncertainties in parameters (for example by varying all parameters in a range 80%-120% of their original values). If detention volumes are added and infiltration on the watershed (scenario 9) is promoted, the probability of reaching the requirements then rises to 76%. In a next step, the costs of the scenarios can be compared with the probabilities of being in accordance with the water-quality recommendations. This leads to a cost-benefit analysis (results not illustrated) that will trigger the choice of technical solutions. In general, numerous technical solutions can be implemented in order to fulfil the defined criteria. The solutions range from source-control to end-of-pipe solutions or technical measures in the receiving water itself. Some of the technical measures are discussed in the new guidelines, however not in details (Krejci et al. 2004b). The idea is to present a catalogue of possible solutions and to give planners space and freedom to focus on detailed solution for any given situation.

2.4 Checkups and survey

The main objective of checkups is to promptly assess that the realisations fulfil the requirements they were designed for. In the new guidelines, at the beginning of the project, a budget for such checkups must be defined. The control of protection measures performances and related costs represent an important innovation. This control will trigger the development of future measures and, therefore, unnecessary or inadequate investments will be avoided at this stage. Short term tests will allow an optimization of the realisation, in term of costs and efficiency. Long term survey is based on regular control of the receiving waters. In particular, the biological and chemical state of the system will be investigated according to Swiss (OFEFP 1998) and/or European (EU WRRL 2000) assessment tools.

3 DISCUSSION

The new guidelines proposed for Swiss specialists are oriented towards integrated water protection measures which are internationally perceived as adequate for sustainable watershed management. Several studies already propose probabilistic methodology to assess urban wet-weather discharges (see eg. EPA 1989, Willems and Berlamont, 2002). The new guidelines have been now proposed to Swiss authorities and field experts active in the field of urban wet-weather management. After this preliminary consultation phase, a final version of the guidelines will be implemented in 2007. The need of a new approach has been accepted by the majority of field experts, even if the complexity of the new approach generates scepticism from several specialists. However, one has to reckon that demonstration projects were still the best way to draw out the benefits of using the new guidelines. In an example, we compared the “classical” approach with the new one proposed in the guidelines (Krejci et al. 2004c). A resulting outcome as an example: substantial economies (1 million euros) in urban wet-weather investments for the village of Möhlin, as the probabilities of impairing the receiving waters were limited. Such kind of experiences highly contributes to the acceptance of the new guidelines. Consequently, we strongly encourage Swiss authorities and/or professionals to publish their results in specific journals to strengthen the use of the guidelines (see e.g.Wilhelm et al. 2006). Nevertheless, the interpretation of probability results is quite difficult and a better communication strategy should therefore be proposed. Several questions must be discussed with the decision-makers/field experts:

- Can the risk of implementing a (relatively inexpensive) scenario with a low probability of meeting the criteria be accepted? Or should we rather implement a more expensive measure from the beginning, which has a high likelihood of meeting the standards?
- Should further investments in an additional examination of the watershed area be granted in order to reduce the uncertainty of the variables and parameters? Or investments rather concern water protection measures which real benefits to the receiving water ecosystems are not exactly known?

Surprisingly, the stochastic aspects of the guidelines were relatively well accepted by all field experts. In fact, the concepts of uncertainty and variability are commonly used in urban wet-weather management, even if not obviously presented. For example, the definition of watershed imperviousness, the choice of rain series, the initial rain losses… are parameters that are commonly estimated in a given range of reliabilities.

One problem was also related to the interpretation of the new criteria: local authorities do not have yet the competences to estimate their numerical values. Specific information is required and short courses (continuous training) will be organised.

For the planning procedure, at present, only the developed software REBEKA is available for the calculation of the criteria. Some engineers complained that the whole assessment procedure can be conducted only with this tool. Thus, it has been decided that the guidelines would focus on conceptual aspects such as immission approach, long term assessment, involvement of uncertainties and surveys. REBEKA will be presented as an example of application. The development of new calculation tools or upgrading of existing one is encouraged.

The checkups of technical realisations, directly integrated within the guidelines, have been well accepted by all endusers. There still is a lack of information about how to conduct such checkups. For the survey in the receiving waters, collaborations with biologists or other environmentalists must be reinforced at both ends. In fact, the specific question of wet-weather impacts is rarely assessed on an individual basis, as the whole biological integrity takes into account all stressors (morphology, dry and wet-weather discharges, etc). As a matter of fact, the assessment of specific impacts of wet-weather discharges requires specific tools and methods (Burton and Pitt 2002) and wet-weather stressors are difficult to isolate from one another. For example, the good quality biological indicators downstream of a wet-weather discharge could originate from the drift of sensible species upstream. Another example can be drawn in urban rivers which are already heavily impacted or/and canalised upstream of the wet-weather discharges. In such a case, the morphology of the rivers and the upstream conditions can hide out the beneficial inputs of control measures.

4 CONCLUSION AND OUTLOOK

The impacts of wet weather discharges on aquatic ecosystems remain an ubiquitous and exciting challenge. New guidelines are proposed in Switzerland to facilitate the design of adequate wet-weather control measures. This “immission” approach differs from the classical “end-of-pipe” approach applied in several countries worldwide. The procedure consisting in placing the receiving waters in the centre of the discussion is expected to bring a significant contribution to a more adequate environment protection. Of course, today’s complexity is higher than in the past and the design of infrastructures cannot be made on the basis of tables or simple calculations. At present, engineers have to deal with receiving water information, water quality parameters, uncertainties and interpretation of stochastic results. A good communication strategy is therefore essential, since all new and renovated infrastructures for wet-weather control in Switzerland will be based on this new approach. We are convinced that our new approach gives a more realistic picture of the situation, especially by taking variability and uncertainties into account. However, we still need more knowledge to understand the relationships between urban wet-weather discharges, flow regime and stream ecosystem responses. Future research programmes must first and foremost include comprehensive, long-term monitoring of the connections /interconnections between urban wet-weather discharges, flow regime in the receiving water and biotic or physical responses of the riverbed ecosystems. Such approach will strongly contribute to the validation of the new guidelines and encourage cross-collaborations between all actors in the field of urban wet-weather management.

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