EUROPEAN APPROACHES AGAINST DIFFUSE WATER POLLUTION CAUSED BY URBAN DRAINAGE

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ABSTRACT
Broader political approaches (legislative, economic, co-operative and participatory instruments) as well as detailed technical measures are investigated for integrated reduction of diffuse water pollution caused by urban drainage. Cost-effectiveness-analysis is used for priority setting and selection of final recommendations among the different measures. In this step solutions in the main fields of agriculture and morphology of waters are also considered in an integrated view. In relation with the water framework directive (WFD) of the European Union the results will be helpful to establish cost-effective action plans in river basin management. Most promising solution is the storm water infiltration as main element of the sustainable urban drainage system.

KEYWORDS : Water protection, sustainability, quality objectives of waters, urban drainage, emission, storm water treatment, cost-effectiveness

INTRODUCTION
Agriculture as well as urban drainage are recognised as important sources of diffuse water pollution with regard to nutrients and pollutants. According to the scientific definition of diffuse pollution (all sources which are directly associated with rainfall-runoff processes) the main urban diffuse inputs are:
- storm water effluents from urban areas drained by separate sewerage systems,
- combined sewer overflows (CSO) from urban areas drained by combined sewerage systems,
- effluents from road drains,
- wastewater effluents, which are not connected to a wastewater treatment plant (WWTP).

Böhm et al. (2000) carried out pollutant input balances for waters in Germany and the reference year 1997. The data for diffuse emissions are based on Behrendt et al. (1999) which are overall confirmed by estimations of other authors. The main nutrient input originates more and more from the diffuse sources while the input load from point sources decreases due to the achieved effect of sewage treatment. It was determined that about 67 % of the total phosphorus load (25 kt P/a) is caused by diffuse inputs. The main pathways of this input are erosion of agricultural soils (33 % of diffuse sources), wash out via groundwater (23 %) and urban areas (4 kt P/a, 16 %). About 72 % of the total nitrogen load (586 kt N/a) comes from diffuse sources. The main pathways of this input are wash out via groundwater (2/3 of diffuse sources), agricultural drainage (21 %) and urban areas (34 kt P/a, 5 %). So in total the urban areas provide 11 % of the nutrients diffuse pollution load.

The share of the total load of all heavy metals for diffuse sources is around 77 % in Germany (Böhm et al., 2000). Within the diffuse input pathways, the most important ones are the erosion of agricultural soils (30 % of diffuse sources) and the urban areas (32 %). The inputs by the effluents from separate sewers and CSO during heavy rainfalls are playing the main role. 15-44 % of the diffuse heavy metal load comes from roofs and roads in the cities during heavy rainfalls. After Hullmann and Kraft (2002) the proportional part of heavy metal load in the river Rhine shows for copper 1.3 % and for zinc 5.2 % originating from metal roofs.

A joint working team is commissioned by the German Federal Environment Agency to evaluate political approaches and investigate technical measures for the reduction of diffuse water pollution on both agricultural and urban pathways. The results for the agricultural sector are presented in three papers at this conference (Lange, Möller et al., Schultheiß et al.). The urban storm drainage pathway will be presented in this paper. Following an earlier presentation at the 6th Conference on Diffuse Pollution which focused on recent technical measures and methods in Germany (Ristenpart and Prigge, 2002) this contribution analyses the approaches throughout Europe in a broader sense and gives recommendations for integrated water protection management.

INSTRUMENTS
The basic instruments for realisation of diffuse water pollution reduction were compiled in a joint paper by the Working group of the federal states of Germany on water problems and the German Federal Environment Agency (LAWA and UBA, 2001):

1. ***state authority principle***
   Appropriate further development of the authority of the state (a proven instrument of prevention and precaution in the past) as the guarantor of high environmental standards.

2. ***market principle***
   Use of targeted economic / market incentives to reduce water pollution (pass on environmental costs in prices) and assessing the efficiency of water protection measures in environmental and economic terms
3. ***co-operation principle***
   Build on co-operative approaches, demand responsible action from those whose activities can impact on water quality (achieve sustainable development at a minimum cost and with a maximum of creativity).
4. ***public participation, rising public awareness, environmental education***
   Information and training or education as an instrument for modifying the behaviour of individuals, social groups and business

APPROACHES

The concrete approaches which are described in this section can all be related to the above basic catalogue of instruments which is used here as structure. On the other hand it is most effective to promote single measures like e.g. storm water management with several of the approaches and instruments.

Legal Regulations

Federal and state standards for wet weather urban drainage discharges.

In a project funded by the German Federal Environment Agency new emission requirements for storm water discharges are set up for their later implementation in a law or ordinance. The discharge into receiving waters is to be limited by quantity as well as by solids load. Groundwaters have to be protected according to the soil conservation act (Grottker, 2003). On the federal states level for separate storm systems requirements only exist in a few German states although its effluents pollution load is comparable (or even higher) to those of the overflows in combined systems. Discharge of polluted storm water should be permitted only after its treatment. Advanced requirements has to be defined according to the state of surface waters quality (see section '*Guidelines ...*').

Requirements for storm water management in state acts.

In some German states (e.g. North Rhine-Westphalia, Baden-Württemberg) storm water infiltration as an important source control measure in new built properties has to be preferred in comparison to conventional drainage systems. In Switzerland also the infiltration is obligatory. In North Rhine-Westphalia even in permitted drainage master plans for existing urban areas storm water infiltration has to be taken into account belatedly.

State ordinances for self surveillance of sewerage systems.

In nine German states such ordinances are already realised (N.N., 1998). The municipalities which are responsible for the operation have to self-supervise their sewerage system and have to report on this to the water authorities. Main aspects of surveillance are the structural state of sewers (e.g. leakage) and accurate operation of overflow structures.

Guidelines for wet weather urban drainage discharges.

The philosophy of the WFD is based on a combined approach of quality standards for waters with supplemental consideration of limit values for emissions. Two recently enacted German guidelines are following this approach. The guideline BWK M 3 (BWK, 2001) was developed for the State of North Rhine-Westphalia for "Derivation of state of waters-orientated requirements to combined sewage and storm water discharge under consideration of local conditions". It enables assessments of the state of receiving waters with adequate efforts. It determines limit values for hydraulic stress and pollution and it additionally defines sections of waters which must be totally kept clear from urban drainage effluents. The guideline ATV-DVWK M 153 (ATV-DVWK, 2000) formulates the objective to minimise the hydraulic and pollution impact of storm water from separate drainage systems. Field of application is the storm water treatment in the context of storm water management. Discharges into surface waters on the one hand and storm water infiltration into groundwaters on the other hand are considered.

Design guidelines for storm water treatment structures

For constructed wetlands (technical references see below) as presently strongly favoured type of treatment structures new design guidelines were developed by some German states (e.g. North Rhine-Westphalia) or are just in preparation by technical associations (ATV-DVWK) respectively.

Economic instruments

Funding.

For some technical measures funding programmes were set up in Germany. For instance storm water management measures (e.g. infiltration structures) are funded by some German states (e.g. in Hesse and North Rhine-Westphalia), municipalities or water associations (e.g. Emschergenossenschaft). Funding rates for the property owners are ranging from 5 to 30 € per square meter runoff producing area disconnected from the sewer system. Some storm water treatment structures like constructed wetlands are also funded by German states to a significant amount (e.g. in North Rhine-Westphalia).

The state funding policies have to be optimised in terms of their efficiency to deliver the greatest possible relief for water bodies. The different fund receiving sectors (agriculture, industry, urban drainage, etc.) have to be evaluated in an integrated approach by cost-benefit analysis. Only those sectors should be further funded where the most effective relief is to be expected.

Wastewater charges.

According to the German wastewater charges act direct sewage effluents into receiving waters are charged in relation to their quantity and pollutant concentrations. Different pollutants are taken into account by specific pollution units. For polluted storm water discharges only special lump regulations are valid. By increasing the pollution units for storm water a charging equivalent to the point source effluents has to be reached. The increased revenues should be used for better funding of storm water management (Böhm et al., 1999).

For the indirect storm water runoff discharges from urban areas into the sewer systems the property users (private, industrial and municipal) have to pay a wastewater fee. This fee has to depend on the quantity of the discharges. Therefore the introduction of split sewage rates is necessary. The foul flow fee is calculated with the help of the amount of fresh water consumed. The storm water fee is depending on the paved area connected to the sewer system. By this means an incentive to disconnect runoff producing areas is given.

In Norway, Switzerland and Germany (as mentioned) the wastewater fee must cover the calculated costs as required by the WFD - the polluter pays principle. In Austria and Portugal exists a subsidy-system, in the first case the costs are covered by the community budget and in the second case other fees within the water sector cover them. Only in Austria, Switzerland and Germany (44 % of the municipalities) a separate storm water fees exist.

Co-operative instruments

EU water framework directive.

The WFD aims at achieving a good ecological and chemical status of all water bodies. This implies an integrated approach considering all the different sources of pollution (agriculture, urban drainage, industry, river development, etc.). An effective pollution control without serious efforts of the agricultural sector will be unsuccessful. In the sense of the above mentioned combined approach the state of waters-orientated requirements have also to lead to strengthened efforts of ecologically developing rivers and streams instead of expensive technical treatment structures. Cost-benefit analysis (see economic instruments) will help to support this integrated approach.

Voluntary self commitments in industry and business

In terms of a more sustainable source control approach and integrated environmental protection commitments of the industry to reduce emissions should be proposed. The companies are asked to voluntarily abandon the use of toxic substances and to substitute hazardous constituents with ones less hazardous to water (e.g. heavy metals in construction industry).

Public participation

Urban water planning

Integrated municipal water plans including optimised pollution control strategies are more effective in the implementation and operation phase when public participation is guaranteed. This information and involvement of the public is required at an early stage in an 'open' planning process. Geldorf (2003) furthermore reported about a 'parallel' planning 'approach where goals, measures and support emerge together out of a process with a lot of interactions between the actors and where planning and implementation are not strictly separated in time'.

Storm water experience.

An important principle of decentralised storm water management (see below) is to make the storm water visible for the public. Attractively designed structures like infiltration swales, open channels, cascades, ponds and waterworks bring back the storm water within the peoples experience. By this means a better understanding of the water system is gained and it is much easier for the public to take responsibility also for water pollution control.

TECHNICAL MEASURES

After the above review of the broader approaches this section closer describes the single technical measures for reduction of diffuse water pollution.

Storm water management

Storm water management concepts are combining unsealing of paved areas, infiltration of runoff from disconnected areas, storm water re-use, distributed retention, delayed transport and treatment (the latter to be described in the following sub-section). The pressure to rethink conventional drainage systems and realise such modern concepts is due to mainly water quantity problems (insufficient hydraulic capacity of sewer systems as well as of streams and rivers) but also quality requirements. In the sense of sustainable development, ecological criteria are taken into account in these drainage concepts which are potentially much closer to nature than the traditional approach has been. The decentralised solutions (e.g. infiltration structures as main element) are used as best management practices (BMP) and are recently named 'sustainable urban drainage system' (SUDS). Practical planning experience shows the necessity to involve drainage planners into town and traffic planning at an early stage because boundary conditions are fixed then which are very important for feasibility and efficiency of the local storm water management concept.

SUDS are a very popular topic in urban drainage in Germany. Beginning with first exemplary projects in the late 1980s which already include investigations of impacts on groundwater quality SUDS are now widely used in drainage planning. The approach is also beginning to be used more extensively in other European countries, e.g. in the UK, France and Switzerland as well as in the US and in Australia.

The first mentioned two elements of SUDS (unsealing and infiltration) as source control measures have a reduction effect on the runoff volume, the others an attenuation effect on the peak flows. Both effects are reducing the hydraulic stress for the receiving waters (disturbance of benthic fauna). Infiltration closes the natural water cycle by increasing the ground water feeding. Böhm et al. (1999) stated an efficient decrease of emissions of hazardous substances into receiving waters (especially heavy metals, nutrients only to a minor extent), but partly these loads are transferred to soils and wastes. Therefore measures at source are necessary in parallel (see sub-section 'Replacement of hazardous substances'). Additionally it is expected that the elimination efficiency of the existing treatment structures improves by 10-15 % in terms of pollutant load emissions due to the reduced inflow rates.

Urban storm water treatment

Storm water treatment is one of the elements of the above described urban storm water management concepts. First aim is to treat only that part of storm water which is really polluted. Therefore a consistent separation of storm water fluxes with regard to their pollution degree is a pre-condition which has already to be guaranteed in the storm water management concept (e.g. infiltration of roof runoff, further treatment of road runoff with heavier traffic load). Infiltration structures itself also show a good treatment efficiency (for less polluted runoff) due to the treatment processes occurring in the top soil layer.

Basins for storm water treatment do exist in Germany only to a small extent. Böhm et al. (1999) therefore expected a significant load reduction by increased construction of efficient settling basins. Due to the controversial efficiency of the basins constructed wetlands (called 'soil filters') are at present strongly favoured in Germany for (advanced) treatment of storm water discharge from combined and separate drainage systems and from roads (Ristenpart and Prigge, 2002). Recent research work showed that the different types of constructed wetlands fulfil their purpose of elimination of noxious substances from sewerage with high performance as well as their water retention function. The suitability of other technical measures for limiting pollutant pressure on waters is evaluated by BWK (2001) and Geiger et al. (2001) and summarised in tables by Ristenpart and Prigge (2002). Böhm et al. (1999) additionally mentioned that in 30-50 % of the cases treatment is due to the poor state of the receiving waters. Efforts to ecologically develop rivers and streams for reducing their pollution sensitivity is an alternative to expensive technical treatment.

Combined sewage treatment has to be improved in Germany by consistent overall realisation of states requirements in terms of construction of retention and settling basins. Böhm et al. (1999) expected an overflow load reduction by around 50 % for SS, PAH and some heavy metals. Reduction rates for pollutants which have a higher soluble share will be significantly lower (e.g. by 20-30 % for COD). These load reduction expectations are based on relatively high controversial cleaning efficiencies.

The treatment of CSO is quite different in Europe. In Germany (as mentioned) and Switzerland a lot of treatment measures for the discharged wastewater are used like storm water sedimentation tanks, retention tanks, screens and brushes. In Austria and Portugal special treatment structures for spilled combined sewage do not exist, only a few storm water retention tanks and sand filtration structure are known in Portugal. In Norway some large cities have retention tanks and screens at exposed places.

Road runoff treatment

Car traffic is a diffuse source of pollution of water, soil and atmosphere. Road runoff is polluted by heavy metals and oils due to abrasion of tyres, brakes and road surfaces, leakage of lubricants and corrosion of crash barriers. This occurs from narrow village streets, city roads and highways with no strict correlation to traffic intensity. According to a Dutch general policy guideline on traffic emissions (Berbee et al., 2002) highways are generally made of porous asphalt. It consists of an upper layer of 5 cm of porous asphalt on impervious asphalt. The runoff contains far lower concentrations of pollutants which is probably a result of solids filtration in the top layer. These solids are transported to the unused hard shoulders by a typ of pumping effect by the tyres. To avoid plugging, the shoulders have to be cleaned periodically. But porous asphalt has a few disadvantages: its lifetime is less than traditional asphalt and it requires more salt for de-icing in winter. Runoff then mostly infiltrates in the verges. Infiltration is controlled by periodical inspection of chemical quality of soil and groundwater. Only in sensitive areas there is an option to route the runoff outside by a sewage system.

In France, Germany and the UK settling basins are more or less used for treating pollutants. But efficiency of removing heavy metals was disappointingly low at 20-40 % and costs are more than a factor ten higher compared to wastewater treatment (Berbee et al., 2002). Investigations at German highways by Lange et al. (2003) confirm the low efficiencies of concrete settling basins but determined much better ones for earth basins planted with reed (67-84 % for SS, COD and metals, 96 % for PAH).

Sewer system inspection and renovation

By sewer inspections leakage leading to sewage exfiltration into groundwater and groundwater infiltration into sewers is detected and has to be rehabilitated. Avoiding exfiltration reduces raw sewage emissions into groundwater. Reduction of infiltrating water allows to use a higher capacity of the continuation flow for the foul flow to the WWTP which reduces overflows into surface waters. Böhm et al. (1999) estimated a reduction of overflow volume by 10 % in case the extraneous water decreases by 50 %. Additionally an increase of the treatment efficiency at the WWTP is to be expected due to reduced dilution of raw sewage.

The performance of CSO structures has to be hydraulically checked. The throttle devices have to prove the accurate limitation of the continuation flow to the WWTP. This assures that the CSO are performing like they are designed and that the amount of overflow into surface water is restricted to the permitted values.

Alternative integrated urban water concepts

In contrast to traditional flushing sewer systems the main principles of alternative sustainable drainage concepts are the consistent separation of wastewater fluxes and their subsequent split flow treatment with adapted technologies. Pilot projects are realised in some countries for new housing development sites (e.g. Germany, Austria, Sweden), but there are also approaches for existing urban areas. The water and material fluxes are as follows:

- Storm water is re-used for toilet flushing, washing-machines and garden irrigation. Surplus storm water is infiltrated into the ground by swales, trenches etc..
- Grey water (from washing, bathing, cooking) is treated in sand filters or constructed wetlands and afterwards re-used like storm water as far as possible.
- Faeces and urine are treated in an anaerobic reactor together with the biodegradable waste. The treated sludge is re-used as agricultural fertiliser. In further advanced concepts the separated urine is directly used as fertiliser substitute without pre-treatment.

Hillenbrand and Böhm (2001) analysed the pollutant fluxes and showed an efficient decrease of emissions into receiving waters (by 60-90% for nutrients, by 45 % for copper and AOX), but partly these loads are transferred to agricultural soils. Additionally the water consumption decreases significantly.

Replacement of hazardous substances

As mentioned earlier measures at source to abandon the use of hazardous substances and to substitute their noxious constituents are needed because they prevent emissions prior to their emerging. This most sustainable approach has to receive unanimous support. In this sense real no-emission substitutes have to have priority over only slightly changed conventional substances with still low emissions. As an example the reduction of heavy metals in construction industry is described in the following. For other pollutants like herbicides (urban weed control strategies) and phtalates (replacement of PVC) similar strategies are known. In general all measures against air pollution take effect at source and reduce rainfall pollution and thus indirectly runoff emissions also.

Runoff from building roofs is a main source of zinc (and copper) emissions due to corrosion and abrasion of roof surfaces and gutters. In 2001 the Dutch government and the zinc industry have agreed that if product innovation and the actual application of the new materials (supported by a promotion campaign) is successful the government will not take action to reduce zinc applications. However, the Dutch government acknowledges the local government's responsibility for solving their local environmental problems and for executing the environmental regulations (Gouman, 2002). To improve zinc as a building material another alloy of zinc which causes less emissions and the possibilities for coating are investigated. The covering of gutters (and other construction elements) with an impermeable EPDM rubber foil reduces emissions by 90 %. To reduce zinc loads on the local scale in Amsterdam for instance zinc roofs on new and renovated buildings are not permitted. Runoff from roofs of existing buildings is allowed to contain a maximum zinc concentration of 200 µg/l. In Germany and Switzerland substitution of zinc by aluminium or stainless steel for roof and façade covering is promoted but worse corrosion behaviour has to be taken into account (Böhm et al., 1999).

For a substantial part the copper load to surface waters is due to the wash out from copper drinking water tubes. The Dutch industry has developed a special copper alloy which reduces copper losses by 30-70 %. Further development is necessary to improve price, safety of production and workability (van Tilborg et al., 2002). In Germany substitution of copper by polyethylene (PEX), polypropylene (PP) and stainless steel is promoted (Böhm et al., 1999).

Dutch environmental policy promotes the substitution of primary building materials (e.g. sand, gravel) by secondary building materials (e.g. bulky wastes like mine stone, steel and phosphorus slag, demolition waste). The latter materials contain various harmful substances (heavy metals), which may leach into ground and surface water. Leuven and Willems (2002) determined the contribution of secondary building materials in river engineering to total heavy metals pollution of Dutch surface waters to be relatively low (<< 1 %). Nevertheless the authors recommended the application of these materials in constructions that are not or to a lesser extent exposed to water flows.

PRIORITIES

Böhm et al. (2002) have examined in Germany costs of measures in the three fields of urban drainage, agriculture and morphology of waters and assessed their effectiveness on water pollution. They are considered in an integrated way to find the most cost-effective combinations of measures. The cost-effectiveness-analysis is then used for priority setting among the different measures. The most important results in the field of urban drainage are:

The cost-effectiveness of measures is showing a wide spread but per pollution unit avoided the costs of the single measures differ significantly over orders of magnitude. This is the case especially for the urban drainage measures storm water infiltration, unsealing of paved areas and reduction of extraneous water. The wide spread of the results is very much influenced by a similar spread of the boundary conditions of each measure but also by the uncertainty related to the effects of the measures. Böhm et al. (2002) therefore proposed more detailed investigations which has to be supported. The assumptions for the favourable conditions of storm water infiltration and unsealing seems to be too optimistic, especially the cost savings due to saved sewer system upgrading. Thus the priority of measures mentioned below has to be carefully interpreted and the results cannot be simply transferred to single cases without going deeper into local details.

In general the cost-effectiveness of measures with low priority under favourable conditions is better than that of the best measures under only mean boundary conditions. Over all storm water infiltration shows under favourable conditions the best cost-effectiveness due to cost savings for the drainage system. However under unfavourable conditions reduction of emissions is very expensive, but on the other hand important effects like reduction of hydraulic stress and solids load of surface waters and groundwater recharge has not been taken into account here. With regard to nitrogen reduction agricultural measures are more cost-effective than further advanced wastewater treatment. With regard to phosphorous reduction storm water infiltration and small wastewater treatment plants are the most effective measures under favourable conditions. A significantly worse cost-effectiveness showed the P-elimination on large WWTP and even agricultural measures. With regard to heavy metals reduction again storm water infiltration is the most effective measure under.

CONCLUSIONS

In general a reduction plan will consist of multiple single measures which have to be balanced and co-ordinated. Cost-effectiveness-analysis is an essential element of setting the priority of effective measures, but there are still large uncertainties in quantifying and comparing costs, effects and benefits. To reach significant emission reductions and to shift to sustainable water resources management different areas of society and policy have to be taken into account (households, municipalities, industry, agriculture, traffic, landscape planning). It is necessary to realise an integrated view of sewer systems, treatment plants, surface and ground waters, agriculture and the morphology of waters. Source control measures are to be preferred because theyprevent emissions prior to their emerging. The chosen approaches will have to cover the whole set of legislative, economic, co-operative and participatory instruments. Most of the measures are of a mid term character. Realisation will not be a task to solve in the near future, but needs to be a continually operated, strategically directed political process for many years.
A main approach which has to be supported in the future are the SUDS. Storm water management with respect to quantity and quality like decentralised infiltration structures and constructed wetlands for biological treatment and retention are favoured measures not only for new building areas. But for existing drainage systems realisation will be a middle to long term task. So in the short term only minor reductions of emissions are expected from this measure.

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