THESES

MANAGING URBAN RUNOFF IN THE LIGHT OF INTEGRATED WATER RESOURCES MANAGEMENT

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Director's assent Supervisor's assent

INTRODUCTION AND OBJECTIVES

The process of urbanization – with all its benefits and handicaps – seems to be unstoppable in the world. The mere fact that practically every second person today is urban dweller in the Earth, and this ratio is even higher in developed countries, while the rate is steeply increasing in the third world, results in consequences related to water management, which needs to be treated with untraditional knowledge, methods and attitude. The concentrated water demands and the amount of released wastewater due to the high population density, the fast response of the urban catchment to the rainfall, the special character and level of the pollution of the surface runoff, the accumulated value of social assets as well as the concentrated water and other types of infrastructure present unique conditions, which should be considered by urban water managers. The complexity of urban water management stems not only from the water supply and sanitation infrastructure but also from dealing with pollution abatement, sustainable use of the resources, surface flow, flood protection, co-ordination between different sectors, etc.

In Hungary the extension of the urbanized areas is significantly increasing due to the development of the agglomeration belts, new investments, constructions of malls, plazas and the migration of the population to the suburbs. The improving amenities, however, results in creating new problems through the changing land use of the catchment. Local authorities, understandably, are not everywhere prepared to find solutions to complex professional problems. At the same time meeting EU requirements imposes further burdens to the communities. According to the obligations related to the public health and to the prevention of infectious diseases, the processes generating pollution must be controlled and measures must be taken to mitigate effects in due course. The countrywide sanitation programme consuming huge financial resources, is a major task for the present and the near future. It offers numerous possibilities to put sustainable rainwater management into practice.

Urbanization has, from the very beginning, required multidisciplinary approach to solve complex water management related tasks. The subsequent changes today are so intense that urbanized areas are decisive factors of river basin management. Cities represent a significant demand for water, due to the concentration of both people and industry. To meet the demand often remote resources are utilized. The important amount of effluent pollutes the recipient and endangers downstream use. The rainwater runoff is often more polluted than the domestic wastewater, due to the pollutants encountered during the surface flow phase or by the re-suspended material of the sewers. With the increase of areas of urban development the hydrological cycle is in a way modified by the infiltration-blocking and runoff accelerating effect of impervious surfaces. This latter is then further increased by the drainage networks (open or underground).

One of the major challenges for humankind will be the solving of the water crisis in the 21st century. Water supply for cities, including meeting the demand for potable and other uses, and collecting and treating wastewater represent already these days an issue of outstanding importance and difficulty. Considering the increasing demand and the depleting of available resources, the quality requirements can be met only with a new attitude in water resources management, as it was formulated by UNESCO emphasising the importance of sustainability (*Figure 1*).

Based on my previous achievements in the field of urban hydrology and drainage the objective of my dissertation is to compile a comprehensive and systemic summary of knowledge, expertise, literature and other types of information available in Hungary and abroad and present them in the spirit of integrated water resources management. As a result I wished to work out a strategic document aiming to help address the challenges of urban water management, with special regard to the issue of rainwater disposition, considering also the consequences of the climate change experienced in our era, and which could hopefully contribute to the sustainable use of natural resources.

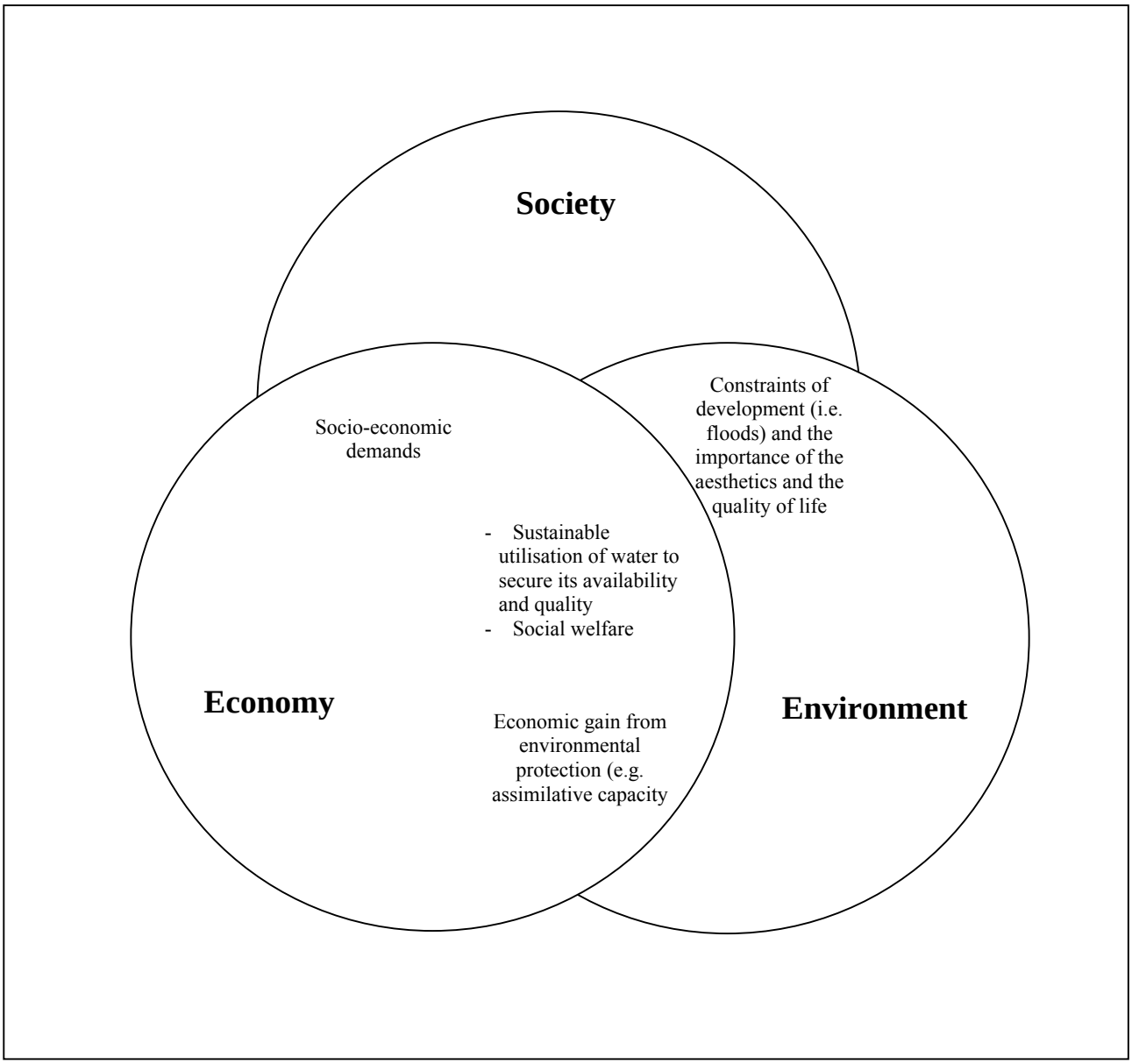

Figure 1. Linkage of society, economy and environment (source: UNESCO 1995)

MATERIAL AND METHOD

Previous research projects carried out in the field of the dissertation were limited in scope. Their importance is remarkable due to the change of social and economic circumstances and conditions, but appreciated only as antecedents in the history of the profession.

More recently new concepts and drainage philosophy have been introduced providing ground to systematize the topics investigated and to present unknown methods of drainage design and rainwater disposition.

The methods applied in the study included the review of water management problems associated with urbanization, their interconnections and the changes expected in the future on the one hand, and the evaluation of the recommended tools from causative point of view on the other. The study encompassed the setting up of an inventory of techniques mostly not applied in Hungary, the systematization of rainwater treatment methods considering both quantity and quality, their critical analysis and the determination of the practical scope of application. Since there is a great deal of „inertia" in the traditional decision making and planning procedures hindering the propagation of the methods presented in the dissertation, the study touches upon the problem of the required attitude change as well.

Amid the changing conditions successful co-operation among the scientists of different disciplines is hardly realized, although integrated measures require the urgent adaptation of a uniform way of thinking. A fruitful co-operation can be achieved only through rethinking the linkages of different sub-areas. The systematization of urban rainwater management can help wisely develop the region affected as well as the settlements. The objective of my study was to contribute to this endeavour by synthesizing the selected topic.

RESULTS

The field of disposing and managing rainwater represent today not only one partial item of the „classical" tasks related to urbanization. One has to consider the tendency of the today seemingly unavoidable climate change (irrespectively if it is the result of natural or anthropogenic effects). As a consequence of the changes the increase of extremities (extremization) is expected, which can be manifested through the augmented intensity of the precipitation and the larger rainfall depth (temporarily), from the viewpoint of the urban water management. This is otherwise superimposed on the changing processes.

To compensate for the unfavourable effects on urban runoff, an integrated management, taking into account both quantity and quality aspects, is needed. For the sustainable disposal of rainwater the so-called Best Management Practice (BMP) is nowadays available, with the use of which pre-development conditions can be nearly reached. The structural and non-structural methods belonging to BMP are little known in Hungary and utilised even more rarely in practice. The Hungarian technical literature has so far lacked the comprehensive presentation of these methods as well as the overall analysis of handling rainwater disposal and management (in the widest context) with all linkages and the problems to solve, although this is fundamental in reaching sustainable urban water management.

Urban water management constitutes one part of the complex managerial system of the city, while the effect of the settlement can extend far beyond the given catchment. The different elements of town management are interacting each other, therefore the networks and the whole systems of water supply and sewerage should fit into the structure and conditions of the city, often determined by other types of infrastructure. The layout of water supply and sewerage networks follows the streets and rows of buildings, while „dual drainage" requires the appropriate lineation of streets. Besides the well functioning water infrastructure, the recreational and aesthetic value of water is indispensable for a „liveable city". In the calculation of the degree of supply of city green spaces, the waterfront and water surface areas hold high value of the correction factor, showing not only a recreational function, but also the effect of conditioning and of the biologically active area. Water is also part of the culture and this aspect is mainly related to the cities. In Hungary it has a unique importance, since water-side settlements possess special „potential energy". Water is a traditional link connecting social processes, built environment and recreation. Urban green space management is unimaginable without appropriate water supply. One of the important elements of town management is the waste collection and management, especially the cleaning and maintenance of public areas. This activity has direct effect on the quantity of material transported by the surface runoff, consequently also on the water quality of the recipient.

Urban water management is an important component of river basin management, since the concentrated demand for water and the discharged effluent of cities substantially influence the status of the basin. In the future the plan of measures should include steps of high priority to compensate the negative effects of urbanization. As a result a strategic document has been worked out aiming to help address the challenges of urban water management, with special regard to the issue of rainwater disposition, considering also the consequences of the climate change experienced in our era. The document would hopefully contribute to the sustainable use of natural resources. With its help the quality and quantity control of urban catchments becomes feasible in the Hungarian practice as well as the conceptual identification of the necessary measures (*Figure 2*).

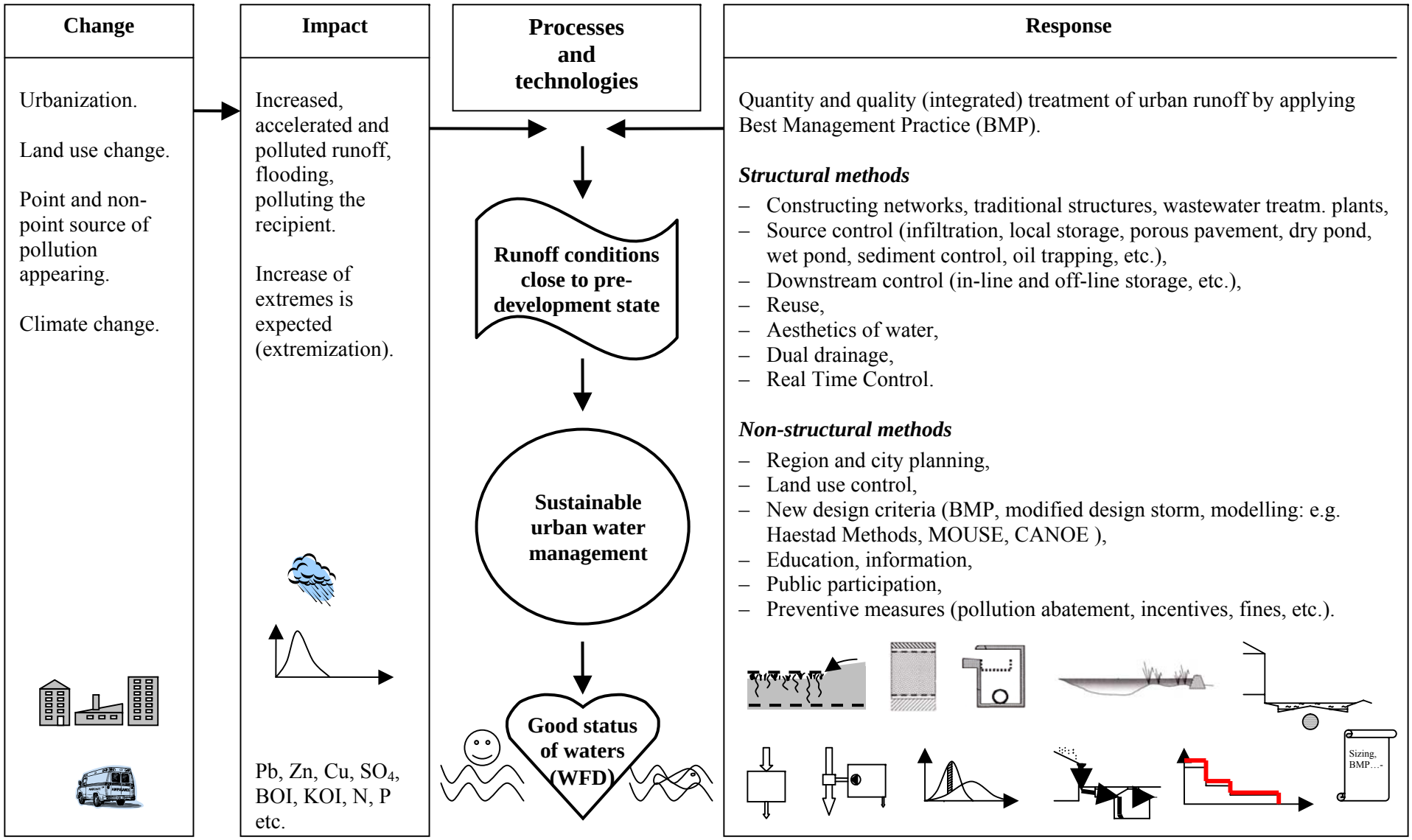

Figure 2. Sustainable rainwater management in the spirit of sustainability (based on the idea of VAHAVA research program)

In connection with climate change a synthetic design storm has been developed, which more realistically mimics advanced rainfall patterns and with the use of which a more correct picture can be achieved of the rainfall-runoff process occurring in nature, therefore drainage systems, more reliably performing in the long-term, can be constructed.

As an additional result of the study several recommendations have been formulated for the environmental policy-making, the practice and the direction of further research. They concern city planning, aesthetics, resource management, risks of utilities, information and public involvement.

New scientific achievements (theses)

Thesis 1

I have pointed out that in Hungary the modernization of the disposal and management of urban rainwater should be treated with priority, since the previous development of the water infrastructure resulted in disproportion on the one hand, and the collection of rainwater should be organized from more and more newly urbanized areas as a result of the rising living standard on the other. The rainwater disposition can be harmonized with sustainable development only if design is based on new and much more complex technical guidelines, in certain cases on local investigation. I recommend to introduce design methods applied in countries who are more experienced in the field than Hungary, as soon as possible. (Examples include Haestad Methods, MOUSE, CANOE.) The solution is supported by the enhanced information technology, providing possibilities for the preparation of significantly more precise decisions. In this course the analysis, the design, the presentation, the agreement with the client, as well as the realization should be based on mutual understanding.

Thesis 2

I have pointed out that one has to be prepared for the pronounced increases of meteorological events, also in connection with urban rainwater management. For the basis of the sizing such design storm should be used, which more realistically mimics time varying intensity of the rainfall and with the use of which a more correct picture can be achieved of the rainfall-runoff process occurring in nature, therefore drainage systems, more reliably performing in the long-term, can be constructed. Analysing urban water related literature I have stated that the runoff is so much loaded with pollution through different everyday urban activities, that it can become more contaminated than the domestic wastewater. This situation requires a new approach to deal with, including treatment of rainwater runoff considering both quality and quantity, taking into account pollutants of different origin, like atmospheric fallout, surface accumulation, sewer deposition. The increasing pollution-load of the environment in urbanized areas can be reversed only with concerted actions.

Thesis 3

To compensate for the unfavourable effects on the urban runoff an integrated resource management is requested to meet quantity and quality requirements. For the sustainable disposition of rainwater the so called Best Management Practice (BMP) is available today, the application of which the runoff conditions close to the pre-urbanization ones can be achieved. Techniques belonging to BMP cover a wide range of structural and non-structural methods, and are little known in Hungary and utilised even more rarely in practice. To promote the application of them I have systemized those solutions, which will be necessary also in Hungary to carry out managerial tasks related to urban waters, with special regard to accomplishing the objectives of the EU Water Framework Directive and accounting for the expected effects of climate change.

Thesis 4

It has been confirmed and stated that as a consequence of urbanization people demand more and more the conditioning urban areas which increase the feeling of comfort, and which can be secured by vegetation and water surface. This latter can be created by constructing storage ponds, while the maintenance of the former can be ensured by water reuse. In both cases the technical viewpoints are coupled with aesthetical values. Different appearances of waters become directly or indirectly part of the structure of the „liveable city" and with the internationally accepted Best Management Practice, they can serve to mitigate the load of the environment. In creating the urban environment and in landscape development the concurrence of urban and rural viewpoints and paying attention to them makes local and inter-local linkages feasible.

Thesis 5

It has been stated and confirmed that with the consequent dissemination of scientific and up-to-date professional results, the new interpretation of water management can be more and more accepted by the citizens. The prerequisite of this is mutual trust building. Resolutions/recommendations of the decision makers become more careful and grounded through the control of stakeholders and transparency. This process can be especially successful if the top-down and bottom-up initiatives meet and reinforce each other. Besides solving the quantitative management of rainwater this approach can result in quality improvement and can be felt in the long haul.

CONCLUSIONS AND RECOMMENDATIONS

As an additional result of the study several new concepts have been formulated for both the practice and the direction of further research according to the following conclusions and recommendations.

(1) The topic of disposing and managing urban waters, which has received due attention in the industrialised countries for several decades, would deserve more interest of the Hungarian decision makers and professionals than the presently expressed, since the issue is prevailing from both quantitative and qualitative points of view.

One of the urban water related impacts of the prosperity following the second world war in Europe and North-America was the increasing sizes of drains, structures and other appurtenances. Since the bigger sizes entailed rising costs, the errors or just smaller mistakes made in the design resulted in important extra costs in the construction. In addition the traditional methods used for sizing was not able to take into account the changing conditions, for instance the storage capacity of sewers. It started to become clear in the 1970s that, inter alia due to the motorization, the surface runoff, supposed to be clear, was not clear any more. Following the recognition many research projects were launched, with the objective to more precisely determine economic, but still safe sizes, and also to detect pollution sources and transport. As a result of spreading the new ideas (considering both quantity and quality) professionals involved in hydrology, hydraulics and water quality control initiated the organization of a conference on „Urban Drainage" in Southampton in 1978. Based on the success of the meeting the representatives of the above fields decided to enlarge the former English-American cooperation and created a correspondence network on urban drainage involving experts in 20 countries. Additionally they decided to establish a conference series devoted specifically to this topic, with regular events every third year. The key of the success of the series was that the experts who earlier had worked separately found several topics of mutual interest. The two relevant international associations (then) the International Association of Hydraulic Research (IAHR) and the International Association on Water Pollution Research and Control (IAWPRC) established a Joint Committee on Urban Drainage, which since then supervises these conferences of increasing interest (see their list in point 1.3).

With the sponsorship of the Joint Committee other speciality conferences are also organized. The increasing number of their participants and publications show the vivid interest towards the field, especially in the developed countries, but in recent years practitioners of developing countries have also sent more and more contributions to these events. Among them the conference series NOVATECH organized since 1992 is of outstanding importance. There special sessions were devoted to the problems of the third world at the last two conferences in 2001 and 2004. This latter event was attended by 600 participants and the size of the proceedings attained 1700 pages. Hungarian attendance, especially the publication of the Hungarian results is little, reflecting the overshadowing of the field. (In the fourteen events only four papers have been published: *Wisnovszky* 1978; *Gayer* 1984; *Wisnovszky* and *Bakonyi* 1987 ; *Csobod* 2001). Also few papers are published in the country.

With the present development pace of sewerage the economic benefit and the long-term environmental advantage of research and of the application of the results is obvious. Compared to the enormous sum of the investments R&D costs are negligible, but the more reliable planning and design, the considerations of different alternatives may save significant amount of money and result in sustainable solutions. The benefit of this latter is not always tangible, but the protection of environmental elements, in certain case their rehabilitation, is also a public concern. Adaptation of foreign results is, although in many case useful, not always successful due to the differing conditions, therefore it should be carried out carefully.

(2) Urban rainwater management is an integrated part of water resources management, and it is also such a part of town management which influences the structure of the city, the dweller's quality of life and everyday living conditions, therefore it should become an important element of city planning also in Hungary.

The river basin as the agreed unit of water management, and the basin approach as the basis of integrated water resources management are generally accepted concepts and form the starting point of the EU Water Framework Directive (WFD). The natural divide of the basin is generally far beyond the border of the settlement concerned, however the effects of the city, both in terms of quality and quantity are remarkable in the basin (or even in the receiving sea). Therefore urban water management should be an organic part of river basin management, the ultimate goal of which – according to the Directive – is to reach good water status, in both quantitative and qualitative terms. It is not feasible without taking into account the impacts of cities. This is referred to as combined approach in the WFD, using control of pollution of both point and non-point source (through the setting of emission limit values and of environmental quality standards).

Town management is a complex series of actions based on decision making, aiming to provide appropriate living conditions for urban dwellers, including water supply and sewerage, drainage, wastewater treatment, i.e. all elements of the water infrastructure. However, it is related in many aspects to places outside of the river basin. In the intersection of the two management units, the sphere of interest of the city and of the basin, there is the urban water management, which should suite to both units. This is feasible only if urban water management fits organically to the city planning, and long-term plans are developed by city planners and water experts together. From among the elements of the water infrastructure those related to rainwater deposition (open ditches, dual drainage, storage ponds, etc.) have the most significant influence on the urban landscape, on forming the surface.

The major role of urban drainage (quantity and quality treatment) is to provide hygiene, appropriate conditions for traffic, to prevent flood and ponding, i.e. it is a fundamental contribution to safe and healthy conditions of life. At the same time the rainwater disposition following the principles of sustainability can offer aesthetics, recreation, culture and other types of experiences, or, on the contrary, bad design, faulty construction or inappropriate operation may deter people from the area. Provision of comfort belongs to the notion of the „liveable city" in the 21st century.

(3) Perceptions related to the resources available for urban usage must be changed, rainwater and eventually the wastewater should be included into the process of use-reuse, contributing by this way to making the water related material cycle closer.

Depletion of available resources is a tendency experienced world-wide. The expected unfavourable effects of the climate change would result in more frequent extreme events, which would negatively influence the availability of the resources. Beyond that, the price of water is increasing due to several reasons, and at the same time the improving household amenities also increase the water demand. All these factors – even in developed countries – have brought the idea of rainwater harvesting forward. Rainwater, which contrary to groundwater is not public property, is suitable to meet several types of water demand in the household and in the garden. Since its treatment does not require special skill, it represents alternative water resources for the owner of the lot. The simplest way (watering the garden) can be already observed, while the technique of utilising rainwater in the house is developing. For putting rainwater harvesting into practice certain change of attitude and technological discipline are essential, consequently the information of the people, awareness raising is needed. A positive side effect of this usage is the easing of the sewers and the wastewater treatment plant. For certain purposes (e.g. as conveying medium) the use of potable water is not justified, therefore the utilisation of rainwater on site, represent significant savings.

Wastewater as resource can be used, first of all, in the agriculture. This requires, however even more significant change of attitude, trust building and persuasion of the population. The necessary technology is already in place and further developing, but since the investment costs are important, it receives less support, for the time being. With the utilisation of wastewater the nutrient load of the aquatic environment and the eutrophication of surface waters can be reduced, and mainly in case of phosphorus it may result in important savings.

(4) Present day level of technology and financial resources practically do not limit the application of traditional methods, the disadvantage of this situation is that Best Management Practice, with its less tangible or intangible benefits, is not supported sufficiently. It is, therefore, imperative to disseminate the techniques of sustainable urban water management, as well as the related systematized way of thinking and attitude change.

As a result of the scientific-technological development a wide range of methods are available for the practitioners dealing with urban water utilities to address the traditional problems arising in the field. These methods are able to provide solutions of high technical level to convey rainwater even from the most dense districts, but with applying many appurtenances, that is with high structural content. Financial resources from different funds are also available for the municipalities, which do take advantage of this. As a negative consequence the old-fashioned „getting-rid-of-water-as-soon-as-possible" type solutions are prioritised to the nature-friend and rational management of rainwater requiring long-term visionary thinking and sectoral co-operation. The quickly demonstrated and spectacular results distract the attention from the so called Best Management Practice, which are sustainable on the long-run, but not easily quantifiable.

The decision makers should be given full information on the long-haul consequences of decisions and of changes and persuaded to give up short-term advantages, which are often only illusory. To make this step is the responsibility of the professionals in order to reach sustainable development.

(5) In forming the urban environment and in the development of landscape architecture rainwater should be given a more important role, because in connection to its disposal and management rainwater may have a function in shaping the urban landscape and presenting aesthetical values.

The adverse effects of urbanization, the appearance of dense, concrete deserts alien to nature, becomes inconvenient even for urban-addict citizens enjoying other benefits of a big city. The migration from Budapest to the suburbs shows people have changed their standpoints and this is serious critics for the urban planning, which paid little, certainly not enough attention to create a liveable, human-scale city, which would offer every day aesthetical and recreational experiences to help renew physical and mental strength. Besides providing public service, a „liveable city" requires several intangible or hardly tangible, but physically appearing elements, many of which are related to water. The location of many settlements by the waterfront determines the close contact with water (several of them is competing for the title „city of waters"), but further parts of them or other cities not gifted with the vicinity of water may claim the appearance of this basic element, directly or at least indirectly.

For the direct appearance of water surface the source control of rainwater offers possibility, simultaneously providing aesthetics, recreation and habitat. This solution helps shape the city modelled on the living organ – as many require – where water plays the role of the vital element.

Direct representation of water may happen in urban parks, groves, which are important water consumers, and which can be supplied with water economically from rainwater ponds during the dry periods. One of the outstanding opportunities of rational management of resources is the

irrigation of parks located in the urban setting, i.e. in the vicinity of even in the middle of large impervious areas, by eco-friendly treated rainwater.

The pre-requisite of such solutions is the co-operation of landscape designers, city planners and water experts. The result can be the creation of a harmonic relation between urban and natural environment for the benefit of all urban dwellers.

(6) Rainwater runoff sometimes may be more polluted than the domestic wastewater, its random character may cause stress-like chock for the recipient, therefore its treatment from both quantitative and qualitative point of view is necessary.

The surface of the urban catchment is polluted due to everyday urban activity, like construction, traffic, littering, etc. Its magnitude, besides the intensity of the pollution sources, depends on the time elapsed since the antecedent rainfall, or the cleaning of streets, made manually or mechanically. Therefore the first flush of rainwater is loaded by pollutants taken up from the surface, especially after a long dry period. Added to this is the re-suspended materials in the sewers and the wet deposition of pollutants in the atmosphere. Summing up the effects proves that the rainwater, supposed to be clear, is more polluted during the so-called first flush, than the domestic sewage. Its pollution load can shock the receiving water body, if its dilution capacity is not sufficient, therefore the quality treatment of the urban runoff is necessary. Handling, managing the runoff quantitatively (storage, infiltration) may well complement the quality related measures.

(7) The public utility related risks must be considered in town management. Although the number of accidents does not attain that of the traffic for example, the risk should not be neglected.

The infrastructure of the settlements, meant to serve basically the comfort of the dwellers, may present a risk factor, which is rarely considered. Cities are underlain by an invisible network of water related utilities, which entails the possibility of endangering those living above. The pressurized water supply pipes may present risk by the potential energy of the water, in case of pipe burst, by the destroying effect. The sewer network, due to its extension, may transport danger developed somewhere to a long distance. The awareness raising of these risks is necessary in general, while the behaviour of individuals towards the built environment requires more care. Lowering the risk is the duty of the city management – working responsibly. City managers should carry out their work with holistic attitude, considering the whole structure of the settlement and the interests of the city dwellers.

(8) Sustainable urban rainwater management requires multi-sided attitude change, both in the field of design-permitting and of the area of education-information-dissemination. The bulk of the problems to be solved includes prevention, involving the public into the decision making process and meeting social-economic expectations.

Sustainable use of water resources requires increased attention of the interveners. Besides decision makers the designers, constructors and operators of facilities, the users at different levels, the competent authorities are all interested in providing water, a finite and vulnerable element, with protection regarding both quality and quantity. Rational use and not misuse, the protection and preservation of resources, the harmless recharge of used water into the natural phase of the hydrological cycle are everybody's interest. Adoption of this perception is especially important in urban water management, because of the large number of urban dwellers, their effect and influence on water. Attitude change is needed also beyond the water saving triggered by the increasing prices. In connection with the utilisation of resources and the disposition of sewage and polluted rainwater we should learn to consider the continuous flow and the cycle of water, also after that it disappears

in the inlet structure or sink. The advantages and long-term benefits of Best Management Practice must be understood by the decision makers and planners. For the attitude change the correct information of the society and the education and training of the young generation is needed. The issue of water should be presented in a way that the knowledge related to sustainable development becomes widely known.

In the past the public was not involved into the decision making process, let alone supporting active roles of stakeholders. As a consequence the top-down initiatives received little support from the society, even if they were in accordance with the criteria of sustainable development. However, the life of all members of the society are influenced by the construction of public utilities, the setting-up of different facilities, the way of solutions, the maintenance practice, etc. Therefore they claim, with good reason, the right to have a say and influence matters, which affect their lives on the one hand, and which they finance by paying tax on the other. For the responsible and meaningful intervention, however, they need to be familiar and to have reliable information in the given issue.

The decision to which the members of the society contributed and which reflect their opinion, will become accepted and its realization will be much more successful, it may even cost less on the long-run, than a solution forced.

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