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WATER BODIES POLLUTION DUE TO HIGHWAYS STORMWATER RUNOFF: MEASURES AND LEGISLATIVE FRAMEWORK

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ABSTRACT

Nowadays, it is a common ascertainment that stormwater runoff in the urban and interurban road network consist non-point source pollution which contributes to the degrading of the quality of water of ground and surface water bodies. Taking into account the fact that water pollution has impacts to people and also to flora and fauna, the need to take measures in order to confront this environmental problem becomes inevitable. The adverse impacts of the stormwater runoff can be minimized with structural and non-structural Best Management Practices (BMPs) or with a combination of them.

Within the content of the present paper the following are included: a) the investigation and presentation of the receiving waters pollution issues from the highway road network stormwater runoff together with the European transport policy concerning the development of an integrated highway road network, b) the examination of the respective pollutant generation and characteristics, c) the presentation of their impacts, d) the examination of the measures (structural and non-structural BMPs), e) the presentation of the "first flush" phenomenon, f) The presentation of the existing legislation in the EU with emphasis in the E.U. Directive 2000/60/EC as well as the presentation of the relevant existing environmental legislation in Greece, including also the presentation of the way the Highway Guidelines actually deal with the specific problem.

KEYWORDS: Stormwater runoff, water pollution, water quality, highways, Best Management Practices (BMPs), environmental legislation.

INTRODUCTION

Transport sector has a significant impact on environment. Transport networks passing through environment sensitive areas could be considered as a potential source of problems like traffic noise, vehicle emissions, transport of hazardous goods, visual intrusion, degradation of receiving waters due to stormwater runoff etc. (Kraetzschmer *et al.*, 2004; Yannopoulos *et al.*, 2004).

Historically, the interest for the runoff of the highway network was restricted to the control of the peak flows in such a way so to avoid floods and their catastrophic impacts. As far as quality is concerned the interest is usually focused to the control of the deposition of sediments and erosion. However, the specific control during heavy raining periods is important but not so enough so to protect the quality and the integrity of the receiving waters (lakes, rivers, wetlands, etc.). For this reason, only few scientists paid the appropriate attention to the impacts of this runoff to the receiving waters. Today, it is a common ascertainment that runoff from the urban and the highway road network consists a non-point source pollution which contributes to the degradation of the water bodies, surface and ground (Gupta *et al.*, 1981; Tsihrintzis and Hamid, 1997; Barbosa and Hvitved-Jacobsen, 1999; Hvitved-Jacobsen *et al.*, 2010). Highways stormwater runoff can carry solid particulates, heavy metals, chlorides etc., which in turn leads to the degradation of the ecosystems. However, given that water pollution has impacts to people, flora and fauna (Tsihrintzis and Hamid,

1997; Barbosa and Hvitved-Jacobsen, 1999), thus making inevitable the need for taking measures for the conformation of the specific environmental problem (Yannopoulos *et al*., 2004).

European Union with Directive 2000/60/EC establishes a legal framework to protect and restore clean water across Europe and ensure its long-term, sustainable use. A management plan and a program of measures must be elaborated for every river basin up to the year 2009. Measures foreseen in this plan must aim at: (a) prevention of aggravation of the situation, improvement and restoration of aqueous systems of ground waters and the fulfilment of the target of their good ecological and chemical situation, as well as the reduction of pollution due to the runoff and emissions of dangerous substances, (b) the protection, improvement and restoration of ground waters, prevention of their pollution and aggravation of their situation and (c) preservation of protected areas. EU respectively tries to achieve a good ecological situation of all water bodies in the Member States by 2015.

The European transport policy aimed at the economic growth and the satisfaction of the requirements of a society which is demanding in terms of quality and safety. This is the right way to develop modern and sustainable transport systems up to the year 2010 (European Commission, 2001). During the last decades, the EU strategies aiming at the construction of infrastructure have resulted in an increase of the length of the highways between the years 1970-1996 by 195% and at the same time they have promoted road transport. Respectively, road transport sector dominates passenger and goods transportation since they control the 79% and 44% share of the respective markets. During the period 1970-2000, the passenger cars fleet in EU has tripled, from $62{,}5x10^6$ to $175x10^6$ passenger cars (European Commission, 2001). In order to ensure the good operation of the internal market and boost the economic and social cohesion, EU Parliament with its decision No.1692/96/EE decided the creation and development of the Trans-European transport network, which on one hand includes the necessary infrastructure (road, rail, inland waterways, etc.) and on the other hand includes services which are needed for the operation of the infrastructure. Road network consists from highways and high quality roads which are supported by new connections (Europa, 2003).

Transport is an issue of high interest for Greece as sections of important road axes are scheduled or are in the construction phase. These parts are either parts of the Pan-European road network or parts of the basic trans-regional country network, i.e. Patras-Athens-Thessaloniki-Evzonoi highway, Egnatia Road, Ionian Odos, Korinthos- Megalopolis-Kalamata highway, Western Thessaly highway, North Thessaly highway, Central Sterea Ellada highway, road access Kristallopigi-Ieropigi, Promahonas, etc. with a total length greater than 2900 kms.

The European transport network aims at the improvement of the accessibility level for all parts of the EU (from outside and inside) in an environment sustainable manner (Premius *et al.*, 1998). The specific network could lead to the degradation of the water bodies in the areas which it crosses due to stormwater runoff unless the appropriate measures will be taken. Transport policies in EU must satisfy economic, social and environmental targets. Accordingly, there is need for strategies in order to control pollution of these bodies from the stormwater runoff in the highway network (Pan-European and highways in the EU Member States) which must be based on the scientific research and reliable data (Yannopoulos *et al.*, 2004; 2006c).

The objective of the present paper is the examination of the framework for the management of the water bodies' pollution from the stormwater runoff in the highway network. That is to examine the type of pollutants which are present in the runoff, their impacts to water bodies, the control measures, the existing legislation in EU and Greece and finally, to make specific proposals for the necessary measures.

POLLUTANT GENERATION AND CHARACTERISTICS

Pollutants in the highways are deposited in the pavement surface, in the refugee islands, in the area near of the highways, etc. During rainfall events, raindrops carry along atmospheric pollutants. The runoff created this way is enriched with various particles and pollutants, which have been overlay or attached to the pavements, shoulders, refugee islands, etc. of the highways. Finally they discharge with direct runoff or through the drainage network to the neighbouring water bodies (rivers, lakes, wetlands etc.).

Numerous factors may affect the quality of highways storm runoff including: (a) traffic volume (roads with traffic volumes over 30.000 vehicles/day) (U.S.E.P.A., 1996; Aldheimer and Bennerstedt, 2003), (b) rainfall characteristics (number of dry days preceding the rain event, rain intensity and volume of runoff), (c) highway pavement type and (d) nature of the pollutants themselves. Apart from the above mentioned general factors, the range of the concentrations of pollutants and their load depend on the specific circumstances of the area or the seasonal changes which can take place. It is noticed that excess loads of solids usually referred to environmental sources and also, to highway maintenance works and not to the stormwater runoff in the highway network (Yannopoulos *et al.*, 2004).

The pollutants which are usually included in the stormwater runoff of highways are: (a*) Solid particulates*, which are thin particulates of dust coming from the surrounding land use, dust and litter transferred by the traffic or produced by the maintenance works (use of deicing agents etc.). (b) *Heavy metals*, like lead, zinc, iron, copper, cadmium, chromium, nickel, manganese, barium, caesium and antimony. As it has been noticed, stormwater runoff of highways include higher concentrations of metals, and especially lead and zinc, compared to water specimens of adjacent to the highways water bodies (Yousef *et al.*, 1985). According to Bingham *et al.* (Bingham *et al.*, 2002), lead, zinc and copper are the most important pollutants in the highway runoff, with the peak concentrations to appear during the first 30 minutes of the rainfall. (c) *Chlorides*, which consist the main part of the stormwater runoff of highways during winter time, mainly due to salt applications. Stormwater runoff may include sodium, calcium, and sulphur due to deicing agents. Sulphur may be due to fuels and asphalt materials (U.S. Environmental Protection Agency, 1996).

STORMWATER RUNOFF IMPACTS TO THE RECEIVING WATERS

Receiving surface and ground waters are both exposed to the pollution sources. Surface waters (rivers, streams, wetlands and lakes) are particularly vulnerable to pollution, because they are directly exposed to pollutants released into the air and which are directly discharged from point and non-point source pollution (Young *et al.*, 1996). Groundwaters (aquifer, karst, etc.) are gradually degraded, as some pollutants slowly percolate downward through the soil at slow rates. However, these pollutants can reach relatively fast the water table through drainage and penetration through fractured rock formations or sinkholes in karst areas. In these cases, aquifers are much more sensitive to pollution compared to the surface waters (Stephenson *et al.*, 1999).

Some of the factors affecting the extent and importance of the impacts of highways runoff on receiving waters are the type and the size of them (lake, river, wetland, etc.), the potential for dispersion of the pollutants, the size of the catchment area and the biological diversity of the receiving water ecosystem. For example, control procedures of transport and fate of pollutants in the case of lakes and reservoirs are different than those of the case of rivers, streams and aquifers. In particular, the most common environmental issue for lakes is the overstimulation of aquatic life. Therefore, for lakes, nutrients are the pollutants of great significance. Streams react in a different way to individual events due to the fact that discharge produces a pulse of the polluting factor, which moves downstream, and deposits can be made at various distances from the place where the pulse is created. Consecutively, the pulse of the polluting factor starts to affect local environment of its depositing. Generally, the most common problem in streams is the suppression of aquatic life from toxic impacts of heavy metals (Driscoll *et al*., 1990). Furthermore, the runoff impact depends on the water quality of the receiver as well as the rate with which pollutants are introduced into the water system. In particular, the high inflow of pollutants during a small time interval into receiving water may produce important changes to the water quality and possible adverse impacts to the biotic habitats. In the case where this phenomenon often repeated, impacts will be permanent and eventually cannot be reversed.

Generally, heavy metals may degrade the quality of the receiving water and may damage the aquatic organisms, since they reduce their photosynthesis, transpiration, development and reproduction. Heavy metals in highways runoff are usually not a toxicity problem, which actually depends, to a great extent, on the physical and chemical form of the heavy metals, their availability to aquatic organisms and the existing conditions of the receiving waters. In particular, water with high total metal concentration of a heavy metal may be, in fact, less toxic than one with lower concentration of this metal but in different form. For example, ionic copper is more harmful to aquatic organisms than organically bound copper (Yousef *et al*., 1985). From the heavy metals the most

prevalent are lead and zinc (Sartor *et al*., 1974; Thomson *et al*., 1997). It has been estimated that 50% of solids and 70% of total polycyclic aromatic hydrocarbons (PAHs), which are found on receiving waters in the USA, come from stormwater runoff of highways (Ellis, 1986).

CONTROL OF POLLUTION FROM HIGHWAYS STORMWATER RUNOFF

The impacts of highways runoff on receiving waters can be minimized through the use of special methods which are known as Best Management Practices - BMPs. There are two types of BMPs: (a) structural BMPs and, (b) non-structural BMPs. The objective of structural BMPs is the runoff trapping with a physical way until the pollutants settle out or filtered through soil layers. Basic mechanisms for pollutants removal using these techniques are gravity-settling, infiltration of soluble nutrients through soil or special filters or with chemical and biological processes. Structural BMPs can be generally considered as measures which can delay, detain and absorb pollutants transferred and transported with the stormwater runoff. These measures include: (a) detention works (detention ponds, extended detention ponds and “wet” ponds, (b) infiltration works (porous pavements, infiltration wells, infiltration trenches and infiltration basins, (c) filtration works (sand filters), d) vegetative works (grass swale and vegetated filter strips), e) wetlands (natural or constructed). The criteria for the selection of the most appropriate structural measures depend on the climatological, geographical and economical parameters, the expected runoff quantity, the kind and quantity of pollutants, the necessary land area, the physical characteristics of the area etc. It must be noticed that various structural BMPs are subjected to limitations as far as the ability to use them and their efficiency to remove the pollutants is concerned (Yannopoulos *et al.*, 2004).

Non-structural BMPs, which can be considered as corrective measures for the confrontation of existing and future problems from the highway runoff, aim at the reduction of the initial concentration and accumulation of pollutants in runoff. Nonstructural BMPs include: (a) land use and comprehensive site planning, (b) pesticide and fertilizer management, (c) litter and debris control, (d) BPMs maintenance, etc. (Yannopoulos *et al.*, 2006a). The interest for the non-structural BMPs focused to the control of sources of pollutants, pollution reduction and prevention as well as to infiltration and processing. In case these measures will be implemented without considering integration with structural BMPS, it is possible not to achieve a satisfactory processing of the stormwater runoff with any of the alternative solutions exists for the respective areas. However, non-structural BMPs can lead to the increase of the performance of structural or other type installations for the processing of stormwater runoff. Non-structural BMPs reduce the need for structural processing systems (or the size of them) of stormwater runoff and at the same time can improve the operation and maintenance of other components of the system (Federal Highway Administration, 2003). Non-structural BMPs must be included in every integrated stormwater runoff management program. It is noticed that management of receiving waters pollution from the highway stomwater runoff with structural and non-structural BMPs is examined in great detail from the authors of this paper in the framework of their papers (Yannopoulos *et al.*, 2004, 2006a).

THE “FIRST FLUSH” PHENOMENON

In urban roads and highways, the initial part of runoff is considered to contain the higher concentrations of pollutants. This specific runoff is known as “first flush” in the international literature (Gupta and Saul, 1996) a term which is not clearly defined (Bertrand - Krajewski *et al.*, 1998). The “first flush” phenomenon is affected by certain parameters like the size of the watershed, rainfall intensity, impervious area and the antecedent dry weather period. It is noticed that concentration peak may vary for the various pollutants during the same rainfall event or in the same watershed during different rainfall events (Wanielista and Yousef, 1993).

Yannopoulos *et al.* (2006b) have presented a literature review concerning “first flush” and they concluded that it is essential to know the distribution of the pollution load coming from the stormwater runoff. Indeed, if the first proportion of the discharged volume (first flush) contains the main pollutant load which is transposed during a rain event, it suffices to intercept only this volume to protect efficiently the receiving water bodies Also, good management of treatment works requires an understanding of the first flush phenomenon of wet weather flow in highways, because the management measures for the pollution from the stormwater runoff often designed in order to collect the “first flush”. Consequently, the problem is particularly important because it concerns the scale of the projects for the stormwater runoff processing and especially the size of the detention-settling tanks.

LEGISLATION IN FORCE FOR THE ENVIRONMENTAL PROTECTION IN EU

One of the basic principles of EU regarding the environment is the pollution control at the source level by the definition of emission limit values and by the establishment of standards for the environmental quality. In particular, the EU policy in this sector: (a) aims to contribute, among other things, at the preservation, protection and improvement of the quality of the environment, at the protection of humans' health, and at the sensible and rational use of natural resources, (b) it is based on the principle of prevention and sustainable development, (c) it stipulates that the environmental protection should be part of the EU policies and actions.

In this framework, EU has issued more than 30 Directives for the protection and preservation of water environment like 91/676/EC on nitrates Directive, 91/271/EC on urban waste water Directive, 74/409/EC on Birds, etc. Among all these Directives, the most important is Directive 2000/60/EC, which institutes an integrated management of water resources at the river drainage basin level. However, this framework is of general content for the protection of the environment and the water resources without actually making a specific reference to the non point source pollution coming from the stormwater runoff of urban roads and highways and associated pollutants.

Within the framework of the development and implementation plans of the Trans-European networks in EU, which accordingly includes the road network, the Decision No.1692/96/EC article 8 stands. According to the above Decision, these plans will be implemented using the Directives 85/337/EC and 92/43/EC, which in fact they have been replaced by Directives 97/11/EC and 96/91/EC. To our knowledge there is no other special Directive, Decision or Regulation in EU legislation which concerns the control of stormwater runoff.

In order to have a complete estimation of the impacts on private and public sector projects, activities and programs, so to foresee the environmental impacts and to achieve a rational management of natural resources, EU was introduced the Environmental Impact Assessment (EIA) procedure. EIA is one of the most important tools for the implementation of the principles of prevention and sustainable development. The implementation of these principles is ensured largely by the ex ante assessment of impact of each type (direct-indirect, small-large, positive-negative, reversible or not, etc.). Environmental Impact Assessment is done according to the Directive 97/11/EC which was amended Directive 85/337/EEC. EU also issued Directive 2001/42/EC (commonly known as SEA Directive) regarding the assessment of the effects of certain plans and programs on the environment. This specific Directive opens new perspectives for the improvement of the Environmental Impact Assessment from plans and programs, among which transport sector and of wastes and of water resources management are included.

GREEK LEGISLATION IN FORCE FOR ENVIRONMENTAL PROTECTION

Directive 2000/60/EC is incorporated in national legislation by virtue of the Law 3199/2003 and the Presidential Decree 51/2007. The above legislation instruments define a general framework for the protection of the environment and the water resources and do not include detailed plans for the stormwater runoff management and associated pollutants of urban roads and highways. Directives 84/630/EC and 85/337/EC, with which the Environmental Impact Assessment became mandatory for all EU Member States, are part of the Greek legislation (Law 1650/86, Joint Ministerial Decisions - JMDs 69269/5387/1990 and 75308/5512/1990).

Law 1650/1986 foresees measures and apply limitations for the protection of water from projects and activities (implementation of technologies for the confrontation of pollution, set of limits for the values of liquid wastes, etc.), care for the quality of water depending on the type of receiving water which must be protected and on the sensitivity of the ecosystems in the study area, creation of a national network of stations for measuring water quality parameters, monitoring of natural recipients, securing of good operation and maintenance of the installations having to do with projects and activities which produce any type of wastes after processing, protection and preservation of nature and landscape, of terrestrial, aquatic or mixed character areas, which are characterized by ecologic, geomorphologic, biologic, scientific or aesthetic importance and thus, need special attention.

Directives 97/11/EC and 96/61/EC are incorporated in national legislation by virtue of the Law 3010/2002 and are also amended certain articles (3, 4 & 5) of Law 1650/1986. Projects and activities are classified in three discrete categories (A,B,C) under the Law 3010/2002, taking into account their environmental impacts as following:

Category A: It includes projects and activities which might have significant impacts to the environment because of their nature, size or extent.
Category B: It includes projects and activities which must follow general specifications, conditions and restrictions, despite the fact that they do not have significant impacts to the environment.
Category C: It includes projects and activities which have a minor impact to the environment.
According to the level of significance of their impact to the environment, projects and activities of category A are classified in sub-categories 1 and 2 while projects and activities of category B are classified in sub-categories 3 and 4.

Decision 1692/96/EC (Article 8) explicitly states that "When projects are developed and carried out, environmental protection must be taken into account by the Member States through execution of environmental impact assessments of projects of common interest which are to be implemented, pursuant to Directive 85/337/EEC as amended by the Directive 97/11/EC and through the application of Directive 92/43/EEC". According to the JMD 15393/2332/2002 highways and motorways, improvement of existing roads in order to be developed to highways or motorways, the national road network in total belong to category A – subcategory 1, while the highways of cross-section C or equivalent or greater, the rural road network and the interurban roads of cross-section D, E or F belong to category A – subcategory 2. Consequently, for all the cases of highways which are mentioned above, the following are needed (article 4, Law 3010/2002): (a) Preliminary environmental estimation and evaluation, (b) Final environmental estimation study. However, for the assessment and mitigation of the impacts on receiving waters from the highway stormwater runoff, the knowledge of its characteristics (concentration, pollutant load, etc.) is necessary. This data is not available in Greece and in many EU countries, because of the fact that the research interest on this topic is quite recent.

It must be noticed that the existing specifications of the Environmental Impact Assessment and the Environmental Impact Study (JMD 11014/703/Φ104/2003, Article 3) are of a general character and they are not customized for the confrontation of the impacts from the highways stormwater runoff. The most relevant to this subject is the guidelines for the Elaboration of Highway Projects Study of the Egnatia Odos S.A. These guidelines determine (Annex 3.1) that «the scope of the hydraulic study is not simply the drain of waters from the pavement but also their disposal to the natural receivers in such a way so to minimize the impacts to the environment». However these specifications do not specially refer to these impacts and also to the measures, which must be taking into account. More especially, section A3.1.1.2. of the Guidelines for the Elaboration of Highway Projects Study includes the following: "these guidelines are neither final nor restrictive". Therefore, this topic remains open, provides a motive for further research and discussion and highlights the need to write and approve special specifications for the Environmental Impacts Assessments.

CONCLUSIONS AND PROPOSALS

Highway stormwater runoff may be a potential threat to the receiving waters (surface and groundwater), if not handled properly and it can become a serious problem. Pollutants, which may be transported via runoff, are solid particulates, nutrients, metals, sodium, calcium, chlorides, etc. Under certain conditions, these pollutants may degrade the quality of water bodies and respectively may have impacts to people, fauna and flora. Despite the fact that the legislation in force of EU and Greece establishes the protection of the environment and imposes the assessment of the environmental impacts to receiving waters from the highways stormwater runoff, the situation is not considered satisfactory because: (a) the characteristics (concentrations, pollutants loads, etc.) of the runoff are not known, (b) the existing specifications for the environmental impact assessment are of general character and they are not customized to the confrontation of the impacts from the stormwater runoff, (c) there is a serious problem with the availability of the necessary data in many EU Member States as well in Greece.

An internationally accepted solution for the management of pollution due to the urban roads and highways stormwater runoff are the structural and non-structural BMPs. The implementation of structural BMPs requires a precise characterisation of the highways runoff composition (number of dry days preceding the rain event, rain intensity), traffic volume, land uses, etc. Differences in the antecedent dry period, the rain intensity, the traffic volume, the land use system in the area crossed by the highway, the type of pavement surface and the drainage method lead to a wide concentrations spectrum for some of the pollutants observed in the runoff (Yannopoulos *et al.*,

2006c). Structural measures should be combined with non structural BMPs techniques in the framework of the best management of highways stormwater runoff. Therefore, the investigation of the impacts of pollution due to highways stormwater runoff to receiving waters is needed together with the issuing of specifications for the appropriate best management measures. Also, research is needed for the determination of pollutants and of the parameters they depend on, as well as for their interrelationship. The research must include extensive monitoring of the quality and estimation of the highways stormwater runoff for different climatologic conditions.

In particular, the following must be made: (a) Determination of the impacts to the receiving waters from the highways stormwater runoff and specifically, in areas which are characterized as protected areas, i.e. areas need special protection according to the legislation in force (Directive 2000/60/EC, Article 6 and Greek Law 3199/2003, Article 4(1)). In fact, these are areas where water pumping takes place for human consumption, areas dedicated to the protection of aquatic species of economic interest etc. (b) Approving special specifications for the evaluation and management of cumulative impacts of highways stormwater runoff on receiving waters. (c) Evaluation of the performance of the BMPs already implemented in countries like USA, Canada, etc. in conjunction with the regulations into action in these countries as well with the respective climatologic conditions, traffic etc. which characterize these countries and Greece. (d) Performing of an integrated management process for the quality of water and the water resources in the framework of which the overall design of the highway, the study, the land acquisition, the construction and maintenance will be examined. This examination will take place in conjunction with the protection of the water resources at a drainage basin level.

River basin management plans, as defined in WFD 2000/60/EC, should take into account possible impacts of the water runoff of the highway road network. These impacts refer to the programme of measures for the fulfilment of the environmental objectives of the Directive concerning surface water and ground water. They also refer to protected areas, to the development of strategies against water pollution and also to the strategies developed in order to prevent and control pollution of groundwater.

In addition, special care should be given to the potential impacts to water bodies from the stormwater runoff of the highway road network during the analysis phase of the characteristics of the river basin district and the overview phase of the impacts of human activity on the surface waters and ground waters. Consequently, the economic analysis of water use, imposed by the Directive 2000/60/EC (Annex III) to the member states, concerning the cost recovery for water services actually suggests the following: the respective cost for the construction and operation of water bodies protection measures should be undertaken by the highway road network users and not by the various sectors dealing with the use of water.

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