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MANAGEMENT OF URBAN STORM RUNOFF QUALITY

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ABSTRACT

In the last few decades it has been recognised that treating industrial discharges may not result in dramatic improvements in urban water quality, especially in lakes, estuaries, and in many streams.

Many water bodies receive a significant amount of pollutants from urban sources. The pollutants are related to change in the characteristics of land by man and other processes occurring in urban water basins. These contaminants are defined as urban nonpoint (or diffuse) pollutants.

Urban nonpoint pollution results from industrial activities, house heating, exhaust emission due to vehicle movements, fine particles from worn off tyres, street litter, septic tanks, pets and other activities. Pollution drived from natural sources can be related to winds, decaying vegetation (leaves, pollen, bark, twigs, seeds, grass, etc.), lit fires, etc. These sources significant quantities of pollutants to surface waters and to the atmosphere.

In this paper management of urban storm runoff quality and the problems associated with the quality of runoff are investigated.

INTRODUCTION

Non point source pollution in the form of runoff from urban areas has contributed significantly to the degradation of flow in receiving waters. After five years of comprehensive research and spending millions of dollars on findly factors affecting eutrophication in great lakes, the International Joint Commission (Pluarg, 1978) arrived at a conclusion that the pollution from nonpoint sources had a detrimental effect.

Wibler and Hunter (1980), in their studies on the Saddle River near Lodi, New Jersey, found that significant sediment enrichments of heavy metals in the lower Saddle River were caused by urbanisation, as compared to the more rural upper Saddle River. Based on studies on catchments near Champaign Urbana, Illinois, Rolfe and Reinbold (1977) found that lead concentrations were much higher in an urban stream (almost 400 mg/L) compared to rural streams in the same area. In the Sydney metropolitan area, pollutant concentration in sewer overflow and storm water flow show that the storm water transports significant quantites of pollutants into the receiving water bodies (Carleton, 1990).

Due to the increasing concern with storm runoff pollution and its impact on receiving water, the management of urban storm runoff quality is an important field of research in Environmental Engineering.

MAJOR URBAN NONPOINT SOURCES OF POLLUTION AND PROBLEMS

In many urban areas, nonpoint sources of pollution, associated with urban storm water runoff causes major water quality problems.

Rain falling or urban areas collects pollutants from the air and land surface. The contribution of storm water pollutants to the receiving water can not be ignored. This is because urban runoff causes a significant increase in the total pollutant load discharged to receiving waters. The risk to public health increases when unacceptable concentrations of pollutants are present in storm waters. Sediment transport in urban areas is another problem which is particularly due to construction activities. Rapid rate of sediment inflow into lakes and streams causes infilling, and in some cases, degradation of ecosystems. The nutrients such as nitrogen and phosphorous exported from urban areas cause eutrophication in receiving waters. Table (1) summarises pollutans, their common sources and problems associated with the quality of urban runoff.

Table (1) Major pollutants, Sources, and Problems Associated with Quality of Urban Runoff (Boroumand - Nasab 1995)

POLLUTANT	SOURCE	PROBLEMS RISK
Nutrients and Algae	Decomposition of organic materials in pastures, street litter (leaves, branches, seeds), pesticides, and detergents.	- Eutrophication of water bodies - Toxic to humans and stocks - Flow reduction due to water weeds
Suspended solids (Sand, Silt and Clay)	Soil erosion, vehicle movements, and construction activities	- Increase in treatment costs - Cause turbidity - Change in river bed elevations - Damage to downstream water users - Alter ecosystem
Heavy Metals	Industrial activities, petroleum products and motor vehicles	- Toxic in nature - Contamination of water supplies
Decomposable materials	Human activities (gardening, waste food products, etc.)	- Depletion of oxygen - Odour - Visible pollution

COMPARISON OF URBAN POLLUTION FROM DIFFERENT SOURCES

Several investigators have compared the pollutant contents of storm water to that of sewage. Weibel et al (1964) noted that storm runoff contains more suspended solids than raw sanitary sewage with BOD, PO_4 and total nitrogen. Whipple et al (1977) concluded that unrecorded pollutants, including those from storm water runoff, may account for more than half of the pollutant concentrations in streams, assuming that all sewage is subjected to secondary treatment. Table (2) illustrates the typical magnitude of concentrations from urban storm runoff and secondary treated sewage effluent (Brown and Molinari, 1987).

COMPARISON OF URBAN AND NONURBAN DIFFUSE POLLUTION

Urban nonpoint source pollution may contain many toxic contaminants such as lead, zinc, asbestos, PCB_S (Polychlorinated biphenyls), oil and grease. PCB_S in urban storm runoff could contaminate the environment and become a most serious nonpoint pollution hazard. Construction activities in urban catchments contribute large quantities of suspended sediments into the receiving waters. In the Menomonee River Watershed (Wisconsin), 2.6% of the total area under construction contributed almost 40% of the sediment loading to the river mouth (Konrad et al, 1978).

Rural nonpoint source pollution is mostly related to agricultural activities. The pollutants may comprise of large quantities of toxic metals, organic materials, pesticides and chemical fertilisers. Pesticide contamination of rural storm water originates from the use of agricultural chemicals to control weeds and pests. Drainage water from agricultural land contains soluble salts, nitrate, and organic material from the soil.

Table (3) illustrates the concentration ranges of pollutants washed off from urban and rural areas. The data given in this table have been collected from many urban and rural catchments in different countries (Jolankai, 1983). Although the concentration ranges are generally higher for rural areas, the urban areas may export higher pollutant loads. This is because urban areas produce a higher volume of runoff per hectare than rural areas and this higher runoff-rainfall factor in urban areas is a general mechanisms for higher pollutant loads. The variations in the range of transported pollutants also indicate that site specific investigations should be employed for design purposes.

Table (2) Typical Magnitudes of Concentrations from Urban Storm Runoff and Secondary Treated Sewage Effluent (after Brown and Molinari, 1987)[a]

Water quality parameter	Urban storm water	Secondary treated sewage effluent
Suspended solids	150-650	10-30
Total nitrogen	0.5-3.0	30
Total phosphorus	0.1-1.5	10
BOD	10-60	20
Total coliform	10^3-10^6	10^5

[a] All units are in mg/L except for total coliform which is CFU/100 mL.

Table (3) Landuse and Concentration Range of Major Pollutants (Jolankai, 1983).

Land Use	NFR (mg/L)	Total P (mg/L)	TotalN (mg/L)	BOD (mg/L)	COD (mg/L)
Urban	5-11000	0.1-1.1	0.2-9.0	0.8-700	5-3100
Rural	18-6700	0.01-12.0	0.1-178	3.0-30	50-780

URBAN WATER QUALITY PARAMETERS

After rainwater falls to the ground, it is either transported over the surface or through the ground as it seeks to reach the sea. The part which passes over the surface may erode away material by either mechanical force or chemical contamination. It may also be subject to the addition of organic material such as leaves, branches, pollen and animal residues. The water which enters the ground may dissolve and leach away underlying strata and as a result, increase the level of contaminants which are present in dissolved or ionic form.

Almost any water quality parameter, whether active or inert, can be critical if it enters into water in sufficient quantity. There are however, a number of chemical parameters which either occur naturally in significant concentrations or which are being introduced into the aquatic system from industrial, agricultural or domestic sources.

The water quality parameters can be divided into several categories such as inorganic and organic or dissolved and solid materials. Some water quality parameters such as nutrients will decay by biochemical means within a reasonable period of time and therefore their effect is not permanent. The other may continue to accumulate into the aquatic system. If the materials are toxic, the long term effect of such a buildup could be hazardous.

Most studies on storm water pollution have been conducted to address the following problems:

- Soil loss from catchment
- Deposition and shallowing of rivers, streams, etc.
- Infilling of water reservoirs (lakes, bays, etc.)
- Increased turbidity of receiving waters.
- Toxicity to humans and animals due to unacceptable levels of heavy metals and toxic substances in water body.

Eutrophication problem due to nutrients and their effect on receiving water quality for potable and agricultural purposes.

POLLUTANT PARAMETERS IN URBAN RECEIVING WATERS

Field monitoring was conducted by US EPA (NURP 1983) to characterise urban runoff flows and pollutant concentrations. To characterise the nature of pollution the study was conducted for a variety of pollutants at different sites throughout the USA. The collected water quality data represents a cross section of regional climatology, soil types, slopes, and landuses. It was concluded that substantial variations occur in urban runoff quality within a particular event and from one event to the next at a given site.

The available urban storm water quality parameters that cause significant problems have been identified by Torno (1984). These pollutants are BOD, COD, heavy metals, faecal coliforms, suspended solids, and nutrients (nitrogen and phosphorus).

Oxygen demanding contaminants are present in urban storm runoff at concentrations approximately similar to those in secondary sewage treatment plant discharges. The discharge of organic and other oxidised materials exerts substantial oxygen demand in terms of BOD or COD on receiving waters. The principal inputs affecting the DO in the storm water flows are municipal and industrial wastes in urban area.

Storm water runoff from urban surfaces is also highly charged with heavy metals such as copper, lead and zinc. End-of pipe concentrations exceed US EPA ambient water quality criteria and drinking water standards in many instances. Some NURP sites found high concentrations of copper and zinc in urban runoff.

Further, urban runoff contains large concentrations of coliform bacteria, viruses and pathogens. These micro-organisms accumulate in both dry weather pipe deposits and in receiving waters and have implications in terms of public and recreational use. Faecal coliform concentration level in urban runoff during warm weather conditions is much higher than that during cold weather. Studies on the sources of bacteria found in storm runoff from residential and light commercial areas indicated the bacteria were predominantly of non-human origin (Quereshi and Dutka, 1979). If significant sewer overflow occurs, this trend may be different.

The infiltration and inflow of storm runoff entering into sewer systems can result in sewer flows. These overflows may occur at pre-designed overflow structures (discharging sewage to creeks) or these may occur at manholes. Both result in the concentrate release of sewer pollutants to the waterbody.

Nutrients are present in urban storm runoff, but with a few individual site exceptions, where their concentration does not appear to be high in comparison with other possible discharges to receiving water bodies. Nutrients (nitrogen and phosphorous) loadings accelerate eutrophication, especially in lakes and can exert subtoxic effects on aquatic organic sediments. Road side gully chambers have been identified as a major source of storm water pollution with the anaerobic digestion of the settled, organically enriched solids, contributing to COD, NH_4-N and BOD, mainly during summer and autumn.

NONPOINT POLLUTION CONTROL

The characterisation of urban runoff quality with its high variability and transient nature presents a difficult task. Pollution in an urban area may come from car parks, roofs, road surfaces, roadside curbs, pasture arease etc. Due to the wide sources of urban nonpoint source pollution, no nuiform technology can be proposed to control the urban diffuse sources. Urban pollution control can take place by preventing or reducing the amount of pollution generated by nonpoint sources to a level compatible with water quality goals.

Livingston and Roesner (1991) pointed out that runoff quality control (and by the same reasoning, combined sewer overflow control) is not yet a technical science rather it is an engineering art, with few design criteria for pollution removal having been established to date. Nevertheless, some empirical rules have been suggested by Novotny and Olem (1994). They are :

1- The most effective runoff quality controls reduce the runoff peak and volume (these are generally infiltration control).

2- The next most effective controls reduce the runoff peak. (These controls generally involve storage).

3- For small storms (those with return intervals of less than two years), the peak rate of runoff from a two-year storm in a preurbanised condition, in order to control stream erosion.

4- Most obnoxious pollutants in urban runoff can be settled out; however, appreciable amounts of nutrients and some heavy metals are dissolved pollutants and require further treatment.

For erosion control in some urban catchments, a sediment trap as a temporary de-silting structure is used at the outlet of a minor subcatchment. Sediment traps are built from hay bales, washed stone, gravel and gabions. Moreover as a physical and bioliogical facility water quality control ponds are also designed to intercept and retain the fine sediment which are not trapped by upstream sediment traps (Phillips and Goyeh, 1987). A study conducted by whiteley et al (1993) showed that suspended solids are controlled more effectively than dissolved solids by using detention ponds.

An effective method of reducing pollution by atmospheric fallout can be disconnecting roof drains from storm sewers and allowing them to drain over a pervious surface. Street litter from urban areas can be conrtolled by eductional programs for citizens, litter control acts and providing well maintained litter collection systems. The NURP results (1983) on the effeciency of street sweeping indicate that this method is effective for coarser particles which make a low contribution to storm runoff pollution, whereas street flushing is more effective for finer particles. However, street flushing is an advantageous and efficient means of control in areas served by combined sewers.

Leaves that accumulate on the streets in low density residential areas are a significant source of nutrients. A program of leaf removal especially in autumn can decrease nonpoint source nutrients.

SUMMARY

Urban nonpoint source pollution is investigated in this paper. Problems and risks for each water quality parameter were identified. The ranges of pollutant concentrations for different water quality constituents from urban and rural catchments were presented.

Comparison of point and nonpoint sources pollutants from urban areas shows that nonpoint sources of pollutants exports significant amount of pollutants. Comparison of storm runoff pollution concentrations in urban and rural basins revealed that the contribution of urban storm water to the receiving water quality can not be ignored. Finally some systems for urban nonpoint pollution control have been reviewed in this paper.

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