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Apportionment of pollution loads arising from catchments in pond water bodies

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ABSTRACT

The paper reports the sources of pollution in urban lentic water bodies (ponds) of Lucknow city. Owing to the unplanned development and urbanization, the ponds of this city are struggling for their existence. In spite of the global alarm for restoration of the water bodies, the ponds in the city are facing neglectance. The city sewage discharge, agriculture and urban runoff and continuous dumping of waste materials especially sanitary waste are affecting the water quality of these urban water bodies. There is considerable need for better understanding of these small impoundments so that they can be managed effectively.

Key words: Impoundments, Lentic water bodies, Urbanization, Urban runoff, Restoration.

INTRODUCTION

Surface water bodies generally get enriched with nutrients but, this natural nutrient enrichment is a very slow process. Man's interference with the lake ecosystem can affect the natural ageing or eutrophication. Due to the industrial development in towns and cities, large quantities of industrial waste and sewage are dumped into the water bodies like ponds, lakes, rivers, streams. Also due to the tremendous increase in population, extensive irrigation has been practised due to which many nutrients like phosphates, sulphates, nitrates, *etc*., find their way to these water bodies. There is no doubt that land use profoundly affects the water quality of ponds, streams, rivers, lakes and shallow aquifers. When precipitation occurs, it cleanses the air and land surfaces like the roof tops, parking lots, agricultural lands, *etc*. In this bargain, it transports a variety of materials like sediments, animal wastes, fertilizers, toxic substances, mine discharges, *etc*., to the nearest natural or man-made collection channel.

Highway runoff

The severity of the impact varies with the type of land use in the catchment area, but several studies have specifically identified urban runoff from highways as a potential source of many contaminants such as nutrients, salts, metals, polyaromatic hydrocarbons and other persistent organic compounds (Legret and Pagotto, 1999). Storm runoff from roadscapes (highways and parking lots) has also been shown to be toxic in various bioassays (Polkowska et al., 2001). There are a number of factors that influence the amount and type of contaminant in storm water even if the land use is fairly homogeneous (*i.e*., storm water from a roadscape). Factors such as the season, the time elapsed since the last rain event and the duration and amount of precipitation strongly influence the concentration of different contaminants in runoff. In some cases, a phenomenon termed the first-flush effect has been observed (Deletic and Maksimovic, 1998) and episodic toxicity of the run-off from roadscapes might therefore also be expected.

Roads represent approximately 20% of urban catchment areas, but their drainage water can contribute 50% of the total suspended solids and 30% of total hydrocarbons discharged directly to receiving streams (Ellis et al., 1987). In

urban receiving waters, the principal pollutants are suspended solids, heavy metals, hydrocarbons and salts with the major sources of highway pollution arising from road and vehicle wear. Road runoff can have a major effect on the hydrologic and physico-chemical condition in the soil and water of natural wetlands. The change of hydrologic conditions can directly modify or change chemical and physical properties, such as nutrient availability, degree of substrate anoxia, soil salinity, sediment properties and pH. Heavy metals such as lead (Pb), zinc (Zn), copper (Cu) and cadmium (Cd) are persistent pollutants which are particularly damaging when short duration intense summer storms follow a long dry period during which these pollutants have accumulated on the road surface, in verges and in the drainage system itself. A sudden flush of road drainage can harm receiving water ecology. More extensive rainfall would have less impact due to the greater dilution of pollutants in the runoff (Mungur et al., 1995).

Agricultural runoff

The agricultural sector is alleged to be the largest contributor to NPP through runoff of nutrients, sediment, pesticides and other contaminants. Crop cultivation requires more use of chemicals and nutrients than natural vegetative cover, such as forests and grasslands. Tillage operations affect the soil structure and often make the nutrient rich topsoil fragile and cause it to lose chemicals and soil particles during rainfall. In addition to agricultural land, land in residential and developed uses, such as lawns and gardens, are managed more intensively, resulting in generation of even more pollutants. Urban areas also have higher percentage of impervious surface that results in lower percolation and higher runoff. During precipitation, runoff carries nutrients and sediment from agricultural and residential land, resulting in higher chemical levels and turbidity in receiving waters. Thus, increasing urbanization coupled with increasing use of nutrients and chemicals in agricultural lands creates significant challenges for water quality protection and enhancement. Recent water quality studies have focused on developing and successfully applying various biophysical simulation methods to estimate levels of NPP and to identify critical locations from which these pollutants originate (Bhuyan et al., 2001). These models use various geospatial data and facilitate the spatial analysis of sources and effects of point and non-point pollutants with reference to their origin and geographical locations. Urban diffuse pollution has been identified as an important cause of surface water quality degradation (Novotny, 1999). Some researchers indicate that it is responsible for the transport of sediment, nutrients, heavy metals, oils, hydrocarbons and pesticides (Schreiber et al., 2001; Lazzarotto et al., 2005). There are many ecological engineering techniques such as buffer zones, ponds, tanks, wetlands and riparian zones currently in use, and they have been shown to be effective in removing pollutants from runoff water (Yin and Mao, 2002). In order to improve treatment efficiency, some of those control measures can be used as treatment trains.

The quality of water in natural inland waters is related to geomorphology, climate and land-use in the catchment (drainage basin). The size and slope of the catchment, precipitation, wind, temperature, erosion, vegetation and soil structure all play a role in the catchment water quality (Schindler, 1997). Land management of the catchment for agriculture, forestry, horticulture, conservation, industry and urban areas influences the quality of water that enters the aquatic system. Agricultural practices such as land clearance, irrigation, drainage, pesticide use, soil enrichment and animal waste will have consequences for the quality and quantity of water in the rivers and lakes in the catchment.

Urban runoff

Urban stormwater runoff not only transport substances washed from streets and buildings but also, domestic and industrial sewage, thus constituting one of the most important sources of diffuse contamination (Carpenter et al., 1998). The effect of urban drainage on receiving water bodies is reflected in their water quality, hydrology and habitat conditions (Sonneman et al., 2001). The contribution of suspended sediments, nutrients and toxic substances is related to urban development, catchment imperviousness and state of drainage systems (Brown et al., 2005). Although some relationships among these factors and macro invertebrates and fish composition have been reported (Walsh, 2000), the aquatic communities of receiving waters have been scarcely studied. The fact that these water bodies are merely perceived as drains may explain why their study has been almost neglected by limnologists (Choe et al., 2002). However, the proximity of the receiving water bodies to their sources of disturbance turns them into sensitive and valuable systems for the evaluation of the impacts produced by the urbanization of a catchment.

As the treatment facilities for point sources expand, the relative importance of the treatment of non-point sources is increasing (Farm, 2002). Discharges of urban water have numerous adverse effects on urban areas and receiving waters, including flooding, sedimentation, temperature rise, dissolved oxygen depletion, eutrophication, toxicity, reduced biodiversity and associated impacts on beneficial water uses. Increased concerns about such impacts led to the introduction of storm water management, a system of control and treatment strategies designed to mitigate such impacts either fully or partly. Such storm water management measures are also referred to as best management practices (BMPs). Diffuse pollution is a complex mixture of different pollutants. Whilst there are innumerable pollutants in storm water runoff, the most common ones are suspended solids, persistent organic matter, nutrients, hydrocarbons, pathogenic bacteria and heavy metals. Harmful poly aromatic hydrocarbons (PAHs) and the potential

carcinogen benzo(a) pyrene have been reported in runoff and sediments. Several recent studies have identified pathogenic microorganisms in storm water runoff. The concentrations of different heavy metals in runoff and sediments have been well established by different researchers and total suspended solids and organic matter indices such as biochemical oxygen demand (BOD) and chemical oxygen demand (COD) are often used to estimate storm water runoff quality. Concentrations and loading rates of contaminants in storm water are highly site-specific due to wide variations in dust fall, average daily traffic and land use in surrounding areas (Settacharnwit et al., 2003). Stormwater pollution is the untreated contaminated water that drains into natural waterways from land uses within an urban catchment. The stormwater runoff can cause hydrological changes in the catchment as well as environmental, social and economic losses. Introducing urban developments, with paved and impervious surfaces, to rural catchments increases surface runoff that is discharged more quickly to the receiving water. Many of the water pollution problems in urban areas are due, in large part, to pollutants that are washed off from land by storms. The stormwater runoff from urbanized lands can change the health of water bodies, impact on aquatic habitats, recreation and aesthetics, or cause algae to grow uncontrollably (Settacharnwit et al., 2003). Contributions to water quality impairment from point sources such as industrial effluent and effluent from sewage treatment plants (STP) can be equal to or even greater than that of stormwater. Pollutant loads discharged through point sources are relatively simple to quantify because the point of entry into the waterways is fixed and the flow rates and concentrations are generally known. Releases are licensed and pollution must remain within license restrictions. On the other hand, stormwater pollution generally has no fixed point of origin and the flow rates are not as well documented. In addition, diffuse source loads are more temporally and spatially variable than are point source loads because they occur only as a catchment responds to rainfall events. Furthermore, pollution from diffuse sources such as stormwater runoff is more difficult to monitor and control.

General sources

General sources include household sources, commercial sources, landscaping practices, runoff from construction sites *etc*. Each household in itself may not be a problem, but the combined cumulative effect of cleaning products, pesticides and fertilizers can be a significant pollution problem. Contamination may result from such practices as improper waste disposal or improper application of fertilizers. This can lead to eutrophication or over nitrification of streams, lakes and wetlands. The streams receiving contaminated storm water may double as a drinking water source. Construction contributes pollutants in a number of ways but it primarily increases sediment in surface waters. Vegetation removal on site exposes soils to the elements increasing erosion. Fuel, oil and other lubricants from equipment, can contaminate ground water as well as surface waters if carried in runoff. The lakes and reservoirs, all over the country without exception, are in varying degrees of environmental degradation. The degradation is due to encroachments eutrophication (from domestic and industrial effluents) and silt. There has been a quantum jump in population during the last century without corresponding expansion of civic facilities resulting in lakes, reservoirs and pond waterbodies, especially the urban ones, becoming sinks for contaminants.

In this context we studied the catchment sources of pollution in the ecological system of Lucknow, which is the capital city of India's most populous state, Uttar Pradesh. Urban growth currently is largely on par with other cities of similar size and is anticipated to be slightly faster in the immediate future. The better economic prospect has lead to an increase in the urban population of the city during last few years. It has lead to large-scale urban sprawl and the inherent distinctiveness of hydrological environment is being neglected in urban planning. With the expansion of the urban sprawl and the increasing population, there has been a surmounting pressure on natural and built drainage systems and also on surface/subsurface hydrological storage units of Lucknow. Our previous studies found that the water quality of the city is polluted as the results were above the permissible limits (Bhat et al., 2009). The anthropogenic factors have also contributed to the presence of heavy metals in the hydrological units of the city. Unavailability of residential areas to the population below a certain wage has lead to the encroachment of wetlands and lakes in the city. The encroachment of these drains and lakes has caused frequent floods in the low laying residential areas of the city and also the depletion of main hydrological features in terms of wetlands and lakes which are main recharge sources to the underlying aquifer.

Pond A

Pond B

Pond C

Pond D

Pond E

Pond F

Pond G

Pond H

Pond I **Pond J**

RESULTS

Several pond water bodies were surveyed thoroughly and the sources of contamination are listed in Table 1**.**

Table 1. Catchment sources of pollution in the ponds studied

S. No.	Name/ Location of the pond	Catchment sources
1.	Maviyahia pond called as Cheer Sagar near PGI	House hold runoff, Highway runoff, Heavy influx of sewage, Runoff from construction sites.
2.	At Mohanlalganj	Agricultural sources, Domestic effluents, Immersion of idols.
3.	At Telebagh infront of Rambarose Intercollege	Highway runoff, Sewage, Household sources, Residential source.
4.	Machlimandi at Telebagh-Charbagh road	Heavy domestic load, Highway runoff, Commercial and residential sources.
5.	At Ruchikhand near Shardhanagar	Domestic load, Sewage, Road runoff, Storm water runoff.
6.	At Aurangabad Jageer behind Ambedkar Maidan	Agricultural and domestic source, Road runoff
7.	Chotakheda near Amausi Airport	Agricultural runoff, Storm water runoff.
8.	Sheeshmahal Talaab near Ghantaghar at Chowk Bazaar	Heavy domestic load, Residential and commercial runoff, road runoff.
9.	Ashwanagar Jeel at Kalapahar, Alamnagar	Agricultural and domestic source, Storm water runoff.
10.	Buttler Palace at Gokhle Marag, Indra Nagar Road	Urban runoff and small scale industries, Runoff from construction sites.

CONCLUSION

With the expansion of the urban sprawl and the increasing population, there has been a surmounting pressure on natural and built drainage systems and also on surface/subsurface hydrological storage units of Lucknow. Unavailability of residential areas to the population below a certain wage has lead to the encroachment of wetlands and lakes in the city. Therefore, it is suggested that the authorities looking into the environmental protection of the water bodies need to take necessary steps. Along with other measures, including strict implementation of central and state level legislation, they should conduct environmental awareness programmes to educate the public of the city and make them aware of the importance of these small impoundments.

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