Impact of storm water on groundwater quality below retention/detention basins

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Abstract  Groundwater from 33 monitoring of peripheral wells of Karachi, Pakistan were evaluated in terms of pre- and post-monsoon seasons to find out the impact of storm water infiltration, as storm water infiltration by retention basin receives urban runoff water from the nearby areas. This may increase the risk of groundwater contamination for heavy metals, where the soil is sandy and water table is shallow. Concentration of dissolved oxygen is significantly low in groundwater beneath detention basin during pre-monsoon season, which effected the concentration of zinc and iron. The models of trace metals shown in basin groundwater reflect the land use served by the basins, while it differed from background concentration as storm water releases high concentration of certain trace metals such as copper and cadmium. Recharge by storm water infiltration decreases the concentration and detection frequency of iron, lead, and zinc in background groundwater; however, the study does not point a considerable risk for groundwater contamination due to storm water infiltration.

Keywords  Infiltrations · Storm water · Retention basin · Groundwater · Trace metal

Introduction

Typically, storm water runoff is introduced into groundwater in one of the three ways; these are sedimentation or filtration prior to infiltration into soil, surface infiltration into soil, and surface injection into groundwater. Urban storm water runoff has long been considered a major contributing factor of non-point source pollution to both surface and groundwater resources. Runoff from impermeable surfaces has been shown to contain significant amount of contaminants such as heavy metals (Cox et al. 1998). Additional studies have indicated that copper, zinc, cadmium, and lead are major components of pollution from urban storm water runoff (Mikkelsen et al. 1997).

Trace metal entering the hydrological system both in the form of organo-metallic and inorganic metal complexes migrate down the hydrological gradient. They are accumulated in different layers of soils, as these are the best known sinks of heavy metal (Dorsis and Warren 1980; Burton 1992), and eventually infiltrate and percolate down into the groundwater. Because the concentration of trace metals in groundwater samples is typically low, it is difficult to ascertain whether a specific trace metal originated from storm water runoff or
was present in the “background” groundwater as a result of natural processes, atmospheric contributions, or other human activities. Therefore, in order to determine the effects of storm water infiltration on groundwater quality while controlling the effects of prevailing land use, ambient (background) groundwater quality is compared with groundwater quality below the selected detention basin in Karachi (Pakistan).

Storm water detention and retention basins have become familiar features in urban and suburban environment where a reduction in impervious area has caused an increase in storm runoff volume. Storm water basin helps to minimize flooding and can improve water quality by allowing solids to settle before they reach receiving waters (Fisher et al. 2003). Though these basins generally provide temporary storage that delays and attenuates peak flows and may remove some harmful constituents, the accumulation of storm water results in increased infiltration rates to the underlying groundwater (Mark 2003).

**Study area**

Karachi is a metropolitan city of Pakistan. It is located in the northwest of Indus river delta and at the north of the Arabian Sea (Fig. 1). Karachi population is calculated to reach above 26 million by the year 2020 (Karachi master plan 2020, 2008). Most of the population concentrated within the urban area of the city and encompasses an area of about 591 km$^2$ (Zubair et al. 2000). There are three major waterways passing in and around the metropolitan city, namely Hub, Lyari, and Malir rivers, which have confluence with the Arabian Sea. These waterways serve the important function of carrying away storm water during the monsoon season.

Hydraulic connections to storm water infiltration is based on groundwater hydrology, soil water characteristic, groundwater flow direction, permeability of vadose and saturated zones, and depth of the water table. Hence, the interactive relationship of water chemistry with hydrological and geological environments could be used to explain the increase or decrease of solubility of certain trace metals in groundwater.

In evaluating the suitability of infiltration basin, the groundwater hydrology plays an important role in determining the chemical constituents present in storm water that are not removed in the soil underlining the infiltration basin. Hydraulic connections between the surface water underlining the infiltration basin reveals that the constituent in the infiltrated storm water runoff which pass through the soil in elevated concentration makes an adverse impact to aquatic life where the groundwater discharges. The elevated potential impact of trace metal in storm water discharge through the groundwater would consider not only the concentration that would occur in the groundwater receiving the polluted storm water but also potential for the polluted waters to enter the water body sediments.

**Material and methods**

A survey has been conducted to establish the quality of groundwater through which storm water infiltrates into the detention basin. The three detention basins were selected for the study; these basin differ in surface area, depth, and number of sampling points but have similar soil covers comprising sand, silt, and gravel and drain storm water from commercial, residential, agricultural, and public properties. All the sampling points are close to the basin and toward the hydraulically down gradient end, as determined from groundwater gradient and topographic maps, in an attempt to increase the probability that the groundwater samples would be representative of the effect of storm water entering and infiltrating through the basins.

In all, 132 groundwater samples from 33 wells were collected during the monitoring period starting from February 2007 to November 2007 (Fig. 2). Quality of water has been monitored seasonally, i.e., pre- and post-monsoon season, and has been analyzed for the trace metals such as copper, cadmium, lead, iron, zinc, and arsenic. In general, rainfall tends to be the main source of recharge of subsurface water. The rainfall in the city is around 200 mm per year based on the last 50-year record (Pakistan Meteorological Department 2007), and the average monthly temperature