Evaluation of environmental impacts of Integrated Industrial Estate—Pantnagar through application of air and water quality indices

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Abstract Large-scale industrialization, population inflow, and rapid urbanization coupled with unfavorable meteorological conditions often induce significant degradation of urban environment. In order to assess the extent of environmental impacts due to establishment of the Integrated Industrial Estate—Pantnagar (IIE-Pantnagar), ambient air and groundwater were monitored from June 2007 to May 2008. Collected baseline information was normalized and interpreted with the application of air (AQI) and water quality indices (WQI). Among the pre-identified air pollutants, suspended particulate matter was found to be the principal culprit to deteriorate ambient air quality, with a maximum annual concentration of 418.5 μg/m³. Monthly average concentrations of respirable particulate matter (aerodynamic diameter < 10 μm) also persist at a critical level with an annual maximum of 207.3 μg/m³. A segmented linear function with maximum operator concept was used to compute AQI, and the developed index was found well suitable to demonstrate temporal variations of ambient air quality. The computed AQI value for the selected study region varied from moderate (97.0) to very poor pollution level (309.2) in respect to developed air quality standards. Furthermore, an integrated WQI was developed comprising 9 parameters, and among all the 10 pre-identified locations, the average groundwater quality was found acceptable in terms of Indian drinking water standards. The maximum WQI (70.6) was found at the Kichha Railway Station during summer months, revealing moderate pollution load. Industrial discharge from IIE-Pantnagar coupled with other industrial setup may hold responsible for such kind of degradation of water quality. In contrast, WQI computed at Rudrapur City demonstrate minimum (15.0–22.1) pollution load. For 95% of the monitoring period, the computed WQI was found acceptable for all selected locations with few exceptions. The application of WQI to assess temporal variations in groundwater quality was therefore found satisfactory.

Keywords Air quality index · Groundwater · Maximum operator · Temporal variations · Water quality index
**Introduction**

Phenomenal growth in population, use of energy, economic transformation, rapid urbanization and industrialization have made enormous ramifications upon the habitability on earth. To assess the extent of environmental impacts in any locality or regions, researchers have developed various environmental tools. Continuous technological advancement leads to generation of huge amount of baseline data related to ambient air and water quality, but these may not provide a clear picture of the surrounding environment (Sharma et al. 2003; Banerjee and Srivastava 2009). In fact, decision makers and the general public need information in a simple and understandable format regarding the levels and potential health risks associated with pollution (Parparov et al. 2006; Nagendra et al. 2007). Moreover, inefficiency of the raw data to provide sufficient information often results in lowering of public interests regarding environmental friendly practices. Furthermore, the success of commitment of a nation to improve environmental quality depends solely on the obligation of the citizens who should be well informed about the current status of the environment. Therefore, the prime importance should be to provide adequate information in a simple format.

The Central Pollution Control Board (CPCB, Delhi) has introduced several air and water quality standards and guidelines in order to regulate environmental quality. Therefore, current approaches for evaluating environmental quality are based on the comparison of monitored values with the respective standards. However, it often becomes difficult to incorporate these standards into a reference scale (Nagendra et al. 2007; Banerjee and Srivastava 2009). Moreover, by providing an upper threshold concentration value in the form of standards, environmental quality tends to get categorized either as good or bad, depending on whether the standards have been exceeded or not (Singh 2006). Even the frequency with which concentrations of pollutants exceed the national standards is not found sufficient by the citizens to assess the actual environmental quality. Dee et al. (1973) suggested that use of standards is only imperative in administrating or to enforce any desired policy, not to appraise environmental quality.

To address the above concerns, the concept of air quality (AQI) and water quality indices (WQI) has been developed in many countries and found effective to evaluate pollution level (Sharma et al. 2003; Banerjee and Srivastava 2009). In general, AQI is used to indicate the level of severity of air pollution with a set of pre-identified parameters. These parameters are universal, irrespective of the level of pollution, and flexible enough to account different levels of population exposure, meteorological variability, and the sensitivity of the target flora and fauna (US EPA 1998; Nagendra et al. 2007). The applicability of WQI to assess groundwater (GW) pollution has also been described in various literatures. Avvannavar and Shrihari (2008) determined the WQI along the stretch of a river basin to evaluate water quality. Parparov et al. (2006) have effectively demonstrated the use of WQI for efficient water quality management.

Therefore, in this experiment, an attempt has been made to evaluate the status of ambient air and groundwater quality with the application of air and water quality indices to evaluate the impacts of industrial and rapid urbanization on the adjacent environment of the IIE-Pantnagar, Uttarakhand, India.

**Study area**

The experimental site is located at the Pantnagar industrial area in the US Nagar district of Uttarakhand, India. The State Industrial Development Corporation of Uttarakhand Limited (SIDCUL), Dehra Dun, has established diverse types of industries at this IIE-Pantnagar. The IIE-Pantnagar is located in the Tarai region of Himalaya with a latitude between 28°59′51″ and 29°01′12″ N and a longitude between 79°24′9″ and 79°26′15″ E. The industrial estate consists of 431 industries, mainly of food production, electroplating, automobile, and allied types spread over 1,310 hectares of