Chapter 7

Conclusions

7.1 General

This thesis has presented the formulation and application of the following three models to assess the impact of urbanization on surface water quality, Water Quality Index model, Urbanization Index model and The Water - Quality Urbanization Regression Model (WQURM). The models developed have been demonstrated on Sabarmati river basin.

7.2 Conclusions

The following conclusions are drawn from this study:

i) The methodology is developed to assess the surface water quality by a water quality model using six physico - chemical and biological parameters, namely, pH, DO, BOD, electrical conductivity (EC), nitrate nitrogen and total coliform.The application of the model is demonstrated on Sabarmati river. The Water Quality Index model is validated using Delphi technique. The model can be applied to any similar surface water body to assess its water quality.

ii) The Urbanization Index model is developed to assess the urbanization level of a location using four multi - dimensional aspects of Urbanization, namely, demographic, economic aspect, spatial and infrastructural development aspect. Under the four aspects identified, nine indicator parameters of urbanization are selected namely, population size, population density, number of Industries, percentage of built- up area, roofing types, electricity facilities, educational facilities, availability of health services and assets (i .e. T V, computer/ laptop, telephone/mobile phone and scooter/car.) have been used to formulate the Urbanization Index model. The Urbanization Index model developed is validated by urbanization level as per Census of India. The application of the model is demonstrated on Sabarmati river basin. The Urbanization Index model can be useful to assess the Urbanization Index of catchment of any station located in a river basin.

(iii) The Water - Quality Urbanization Regression Model (WQURM) is developed to assess the impact of urbanization on the river water quality and to predict the Water quality of a river for a future growth of urbanization.

The application of Water Quality - Urbanization Regression Model (WQURM) is demonstrated on the Sabarmati river basin. From figure 5.17, the WQURM linear mathematical model derived is $y = - 0.5708 x + 86.054$ for Sabarmati river basin, where, y = Water Quality Index and x = Urbanization Index of the stations under study.
$R^2 = 0.94$ ($p < 0.05$) shows that there is a good fit to the data. Also 94 % of the variation in WQI can be explained by the UI. The trend of the line shows a negative correlation between the two parameters.

The WQURM formulated in the present study is validated on Mahi river basin. From Figure 6.12, the linear WQURM model obtained for the Mahi river is $y = - 0.8999 x + 119.62$, where,
y = Water Quality Index, x = Urbanization Index of the stations under study.
$R^2 = 0.82$ shows a high degree of correlation between the Water Quality Index and Urbanization Index for the Mahi river. The trend of the line shows a negative correlation between the two parameters, which is same as the trend obtained for the Sabarmati river basin. Hence, the WQURM formulated in the present study is validated.

The WQURM model can be generated for any river to predict the river Water Quality for a future growth of urbanization, using the methodology formulated in the present research.

(iv) Correlation between Water Quality Index and Urbanization Index of the stations located on Sabarmati river:
From the Water Quality Index obtained for stations S_1, S_2, S_3, S_4 and S_5, the following conclusions are drawn :

The Water Quality Index of station S_1 (i.e. 49.1) shows that the water quality at this station is bad. Stations S_1 lies in upper reaches of Ahmedabad district and its catchment area consists of

districts - Sabarkantha, Mehsana, Banaskantha and Gandhinagar district. Hence the Urbanization Index of station S_1 is high.

The water quality observed at station S_2 (i.e. 76.4) is good. Station S_2 is located in moderately rural area of Kheda district.

The Water Quality Index of stations S_3 (i.e. 79.8) and S_5 (i.e. 80.6) shows that the water quality at these stations is good. Stations S_3 and S_5 have low Urbanization Index .The catchment of station S_3 is a forest area, whereas catchment area of station S_5 consists of moderately rural area of Sabarkantha district.

The Water Quality Index of station S_4 (i.e. 38.1) shows that the water quality at this station is bad. Station station S_4 is located in Ahmedabad district. The catchment area of station S_4 consists of districts- Sabarkantha, Mehsana, Banaskantha and Gandhinagar and Ahmedabad district. Hence the Urbanization Index of station S_4 is high.

Overall, from the results obtained for the Water Quality Index and Urbanization Index of all the stations under study on Sabarmati river, it is observed that those stations with urbanized catchments have a deteriorated water quality compared to those stations having low/ moderately urbanized catchments. Hence, it can be concluded that with the increase in urbanization levels of the station, its water quality deteriorates with a linear pattern and it is mathematically verified in this study.

(v) Spatial variation and Seasonal Variation of Water quality for the stations on Sabarmati river:

Figures 5.1.1 to 5.1.5 show the seasonal variation of water quality. It is observed from the graphical representation that stations S_1 and S_4 which are indicating the highest urbanization have the highest seasonal variation followed by station S_2. While lowest seasonal variation is observed at station S_3 and S_5 which is indicative of lowest urbanization. The Water Quality Index in summer is lowest for all the stations followed by winter and then post-monsoon.

It can be concluded that those stations with high urbanization show a higher seasonal variation of water quality than those stations with low/ moderate urbanization levels. This may be due to the effects of urbanization and urban activities on the river.

Figure 5.2 shows the spatial variation of the water quality of the stations. It is observed that the Water Quality Index at S_4 is lowest, which is highly urban followed by S_1, S_2, S_5 and S_3 which are lower urbanized, for all the seasons. This is indicative that as the urbanization of a location increases, its water quality deteriorates.

7.3 Research Contributions

- There exists an intrinsic relationship between urbanization and surface water quality. Although this relationship is difficult to appraise, is simple to comprehend. Urban areas contain many people in relatively small areas, and the activities of these people produce pollutants and cause pollution. Some pollutants are discharged into the surface water bodies affecting quality of surface water. Thus uncontrolled urbanization poses major challenge to maintaining quality of surface water bodies. The research has presented the methodology to measure the influence of urbanization on surface water quality in a scientific and quantitative method using various water quality and urbanization indicator parameters. The methodology presented in the research is distinctive and not been done in the past.

- The Water Quality Index model developed in the present study is applicable to Gujarat. The model is developed with extensive ranges of the water quality parameters. Hence, it is an improved version of the Water Quality Index model compared to other models found in the literature for Indian scenario. It is can be used as a water quality assessment tool to the government authorities, the scientific community and the public, to assess the quality of rivers relative to human and aquatic ecosystem health, and global environmental concerns. The water quality model developed can be used to define the status of river water quality and to identify and quantify trends in water quality. It can be useful to provide the accumulated water quality status in a form that resource management and regulatory agencies can use to evaluate alternatives and make necessary decisions.

- The Urbanization Index methodology presented in the research is distinctive to estimate the urbanization level of a district using four multi dimensional aspects, i.e, demographic, economical, spatial and infrastructural development aspects. Further, the research also presents a methodology to evaluate the urbanization of the catchment of a station on river to assess the impact of urbanization on water quality at the station. The Urbanization Index model formulated can be used as an essential tool to estimate the Urbanization level for influence of urbanization on various aspects of environment.

- The WQURM model evolved can be used as a tool to predict the river Water Quality Index from the Urbanization Index of the location and to assess the influence of urbanization on the river water quality. Based on the predictions of status of water quality, policies can be proposed by policy makers and/ or government regulatory bodies to promote the urbanization processes in a scientific manner so as to curb the water deterioration problems and carry out sustainable economical development without affecting the quality of surface waters.

7.4 Scope of future work

In the present study, the models are derived using six indicator parameters for water quality assessment and nine indicator parameters for urbanization level assessment. The models can be framed by using more parameters for assessment of water quality and urbanization.