CHAPTER 2

REVIEW OF LITERATURE
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This chapter consists of the significant research work relevant to the problems of pollution in surface water and groundwater carried out by scientists, research agencies, NGOs and government organizations. The summary of previous work is not restricted to the Ghaggar River Basin and includes the mention of some notable work having bearing on the problem, done in other parts of globe. There is an exhaustive literature available on quality of surface water, but mention here is made of only significant work done at national and international level.

2.1 SURFACE WATER/RIVER WATER


Clarke (1924) pointed out that in more humid and fertile regions where vegetation is abundant, bicarbonate is commonly the dominant anion, whereas, sulfate and chloride commonly predominate in the more concentrated river water of arid and unproductive areas. Coffing (1937), while working on the White River canal concluded that in general the temperature seemed to be primary factor influencing production. It is realized that temperature influences the chemistry of surface water greatly.

Conway (1942) has already dealt with the influence of geology upon the composition of lake and river waters in its general aspects. Therefore, geology also affects the water chemistry e.g. water flow through crystalline rocks contains low proportions of major ions while that draining through the sedimentary rocks contains more ions.
Tucker (1958) studied the impact of seasonal fluctuations on a number of chemical constituents of the water. He observed that (i) the highest value for total alkalinity was noted during summer and early autumn and minimum value occurred during the winter months, (ii) in contrast, the maximum values for total hardness and calcium occurred during the winter and the minimum values were observed during summer and early autumn.

Casey and Newton (1973) observed the chemical composition and flow of the Frome River and its main tributaries. They reported that in the water, alkalinity and calcium were decreased at the time of flood.

Reid and Wood (1976) concluded that temperature was a controlling factor for the aquatic organisms. They further reported that chloride was a critical factor in the distribution and maintenance of many organisms. The nitrate intake was not influenced by phosphate but phosphate was influenced by it.

Maas and Hoffman (1977) considered crop salt tolerance as the most important factor in evaluation of water quality for irrigation. Kirda (1997) observed that (i) quality of irrigation water is not constant over the seasons, (ii) salt concentration of rivers, lakes and reservoirs increases during summer, (iii) while, the salt concentration change is only 10-20% in the large bodies of water, it may be as high as 100% in small bodies, (iv) whereas, deep groundwater wells show considerable changes. He considered seasonal fluctuations one of the important factors while assessing the quality of irrigation water.

According to Arienzo et al. (2001), increased level of pollution in river was linked to relative growth of industrial and urban activities. They further found that concentrations of most of the contaminant were particularly high during summer due to less river water available for dilution.

Linnik and Zubenko (2000); Campbell (2001); Lwanga et al. (2003); Lomniczi et al. (2007) expressed the similar views and confirmed that runoff, atmospheric deposition and domestic and industrial effluent discharges were the major sources of water pollution.
Muwanga (1997); Anderson (2003); Babel and Opiso (2007); Samarghandi et al. (2007); Igwe et al. (2008); Al-Juboury (2009) reported that trace amounts of heavy metals are always remain in fresh waters due to the weathering of rocks and soils.

Emoyan et al. (2006) have also made significant contribution towards the toxicity of heavy metals in the river water. They concluded that the unregulated discharge of contaminated effluent from industries and communities is responsible for river pollution in downstream sites.

Igbinosa and Okoh (2009) expressed the similar views and concluded that discharge of inadequately treated effluents from the wastewater treatment plant have impact on the physico-chemical characteristics on the receiving water body.

Awofolu et al. (2007) stresses upon the importance of regular assessment of the pollution and the influence of wastewater on the receiving aquatic systems and it become obligatory in case water bodies are used for domestic, agricultural and recreational activities. They further warned that ruminants depend on wastewater irrigated grasses might be at the risk of bioaccumulation which can alter the food chain.

According to a study, water contaminated by effluents from a variety of sources is associated with heavy disease burden (Okoh et al., 2007) and this could influence existing shorter life expectancy in the developing nations as compared to developed nations (WHO, 2002).

Girgin et al. (2010) studied the relationship between aquatic insect species and trace elements in an urban stream using multivariate techniques. They noted sensitive orders of aquatic insects that reflected the water quality of the stream.

Sekabira et al. (2010) identified two sources of pollutants in water using factor analysis (FA); (i) mixed origin or chemical phenomena of vehicular and industrial emissions, and (ii) dual origin of Zn (e.g. Vehicular, commercial and industrial establishment).

Many workers have also studied the physico-chemical and heavy metal pollution and various other aspects of Indian rivers to assess the quality of water.

Misra and Yadav (1978) have done a comparative study of physico-chemical characteristics of river and lake water in central India. They reported that lake water was high turbid, rich in organic matter, contained more of chlorides, and had a higher pH as compared to river water.

Sarin and Krishnaswami (1984) indicated that in the high land rivers calcium, magnesium and bicarbonate are the most abundant dissolved elements in waters of all seasons. They have also determined sodium over chloride ratio in both high land and lowland rivers and the excess of sodium is attributed to silicate weathering.

Sarin et al. (1989) concluded that carbonate weathering is the main source of major cations in the Himalayan Rivers.

Aggarwal et al. (2000) studied the impact of domestic wastes and wastewater containing heavy metals on the water chemistry of the River Varuna. They have stated that wastewater discharged to the river has increased its temperature, pH, alkalinity, chloride, phosphate, potassium, magnesium, cadmium, copper, iron, zinc and lead.

Mohanta et al. (2000) described water quality index (WQI) of the River
Sanamachhakandana, Orissa. They observed that potability of river water was much less, than the permissible levels of various agencies.

A survey on water quality of the River Ganga was made to assess the fluctuations in physico-chemical and bacteriological variables for four consecutive years by Dwivedi et al. (2000). WQI values indicated deterioration in water quality towards the downstream side due to addition of sewage discharge at successive downstream sites all along bathing ghats of the river.

Rathor (2001) undertook a comprehensive study on the water quality of the River Gomti at Lukhnow city at entering and outgoing points during different months of the year. Their study revealed significant seasonal variations in the physico-chemical parameters. They have reported that effluents from urban waste, drainage and untreated wastes were responsible for river pollution.

Mishra and Tripathi (2001) studied the physico-chemical characteristics of the Ganges River water at monthly intervals for two years to determine impact of sewage discharge on the river water. They reported that control sites possess higher dissolved oxygen and lower total hardness, acidity, total alkalinity and chloride contents. A reverse trend in the values was observed at the point of maximum sewage discharge into the river water. Analysis of variance revealed a significant (p < 0.01) variation in the values between sites and between months. The values of total hardness, acidity, total alkalinity and chloride were positively correlated, however, dissolved oxygen showed a negative correlation with above parameters.

The water quality of the Ganga River has been interpreted by factor analysis (FA) for a period of three consecutive years. FA (R-mode) indicated that the Ganga River was mineralized between Fatehgarh to Kannauj, which is the lower reach and no mineralization between Narora to Katchla, which is the upper reach of the research area. It also summarized that major pollutant sources for the river were due to anthropogenic activities at some sites and domestic and industrial waste at some other sites.

Roy et al. (2001) have reported heavily deteriorated water quality of three rivers bordering the Ranchi. Among them organic matter and inorganic substances,
e.g. iron and calcium, heavily polluted the Harmu River water. Nanda and Tiwari (2001) to determine the effect of discharge of municipal sewage on the water quality of river conducted a study. They reported that river was significantly deteriorated after discharging of municipal wastewater into it.

Saxena et al. (2001) have done an extensive study on presence of heavy metal in the River Ramganga and its impact on Cucumis Sativus L., if irrigated with this polluted water and its recovery through aquatic macrophytes. The physico-chemical characteristics and annual average values of trace elements in water and sediment of the river exceeded the tolerance limit. Hence, this further affects the environment and causing metal bioavailability. They reported that heavy metals (i.e. Fe, Cu, Zn and Pb) concentrations were above the permissible limits except few upstream sites. They concluded that the water pollution inhibited the seed germination and suppressed the photosynthetic activity after using in irrigation. Heavy metal concentration in river water was decreased by aquatic macrophytes. Lemna minor and Wolffia globessa were useful in recovering trace elements from River Ramganga water.

Gopal and Zutshi (2001) worked on the health of various aquatic ecosystems focusing on the Ganga River and Dal Lake. They concluded that health of Indian ecosystem has been deteriorating very fast, particularly during the past few decades. They suggested immediate remedial action for arresting further degradation, and putting the system on the path to recovery. Distribution of trace metals in water, suspended and bed sediment of the river system, India, was calculated by Jain and Sharma (2001). They observed negative correlation between amount of flowing water and heavy metal concentrations.

Kaur et al. (2001) designed a mathematical formula based on nine physico-chemical characteristics to assess water pollution level of the Satluj River. They determined the water quality of the river in term of its being unpolluted, slightly polluted, moderately polluted, excessively polluted and severely polluted, based on a study conducted for a period of four years. Three classes of water have been identified in the river. These were classified as class I (WQI, 80-100), representing clean to slightly polluted water; class II (WQI, 60-80), representing moderately polluted water and class III (WQI, 0-60), representing excessively and severely polluted water.
Garg (2002) has also linked the fluctuation in physical and chemical characteristics of river water with seasonal variation. Jain (2002) found industrial wastewater was responsible for degradation of water quality while working in the upper stretch of the River Hindon.

Pawar and Joshi (2002) studied the impact of urbanization and industrialization on water quality of river. They have suggested some remedies such as prevention of mixing of untreated sewage in river, setting up water testing laboratory at water treatment plant and creation of awareness among the people through arranging various programs and demonstrations.


Fokmare and Musaddiq (2002) have done a study on physico-chemical characteristics of the Kapshi Lake and Puma River waters in Akola district of Maharashtra. They have estimated that the higher values of phosphates in the Puma River can be attributed to pollution from detergent and domestic waste.

Ramamurthy et al. (2002) investigation revealed that there was an increase in level of mercury in the Paravanaru River, due to discharge of water from fly ash ponds and coal washeries.

Aher et al. (2002) ascertained impact of human activities on the quality of water in the Pravara River Basin and Pravara left bank canal. They analyzed water samples for temperature, pH, carbonate, calcium, magnesium, phosphate, hardness, sodium, total dissolved solids and sulphate and found changed physico-chemical characteristics of the river water at downstream sites due to anthropogenic activities.

Kumar and Meenakshi (2002) calculated WQI based on some physico-chemical parameters to evaluate the water quality of the Sai River at Rae-Bareli. It was concluded that the values of WQI were very high as compared to the drinking water standards and the river was severely polluted.

Bordoloi et al. (2002) indicated an anthropogenic contribution from the urbanized part of the city and called for continuous geochemistry monitoring of the
soil and water. During study, water showed fluctuating behavior in different parameters throughout the course of river. The observations of Kumar and Shukla (2002) on the river water indicated the role of human activities in deterioration of water quality.

Sinha et al. (2002) called for immediate action to control pollution after analyses of bioaccumulation of heavy metals in different organs of some of the common edible fishes in the river water.

Mehra and Kaur (2002) studied epiphytic community on the roots of water hyacinth in relation to the physical and chemical variables to assess the impact of sewage and industrial waste disposal on the receiving water of the River Yamuna in Delhi. Higher diversity and species richness of phyto-epiphyton on the roots of water hyacinth were observed.

Mushigeri and David (2003) studied the impact of paper mills effluents on the aquatic ecosystem and fishery potential of the River Kali. They reported change in physico-chemical characteristics of the aquatic environment and found decreased fishery potential nearer to the discharging points. Jayaraman et al. (2003) examined water quality of the river and noted spatiotemporal variations in some physical and chemical parameters.

Gopalswami et al. (2003) conducted a study on the quality of water in the Bhavani River. They have pointed out that the Bhavani River was highly polluted by letting out industrial effluents, agricultural runoff and sewage into the stream. Proper treatment and disinfection of water before use for industrial purposes and human consumption were recommended.

Gandhi (2003) have done a preliminary study to assess genetic damage in some residents of Mahal village of Amritsar, who were using groundwater sources, polluted by effluents heavy metals from various industrial and municipal units. DNA damage in peripheral blood lymphocytes revealed that comet tail lengths far exceeded the values in an age and sex matched control group.
Liyaquat et al. (2003) assessed the acute and chronic toxicity of zinc to different freshwater animals. They found freshwater animal’s species very sensitive to zinc and zinc smelter effluent acute toxicity. They also concluded that even 5 mg/l permissible limit of industrial zinc discharge is unsafe for aquatic life especially in the presence of other metals.

Manna and Das (2004) assessed the impact of the River Moosi pollution on the River Krishna. Results indicated a perceptible water quality change in the Krishna River caused by the Moosi River that transports industrial and municipal wastewater. In this study, the Moosi River exhibited much higher values of limno-chemical parameters versus those in the River Krishna.

Sharma (2004) examined the River Beas water to assess its suitability as drinking water. He has noted that water was moderately hard, dominated by carbonate and bicarbonate with calcium and magnesium. He emphasized on the need of removal of high turbidity and proper treatment of the river water.

Zafar and Alappat (2004) observed that river water quality was affected by the landfill site surface runoff. It has been contributed to river pollution in a significant way in the form of surface runoff from landfill site, especially in rainy seasons. They concluded that this is one of the causes of river pollution apart from other major municipal and industrial sources.

Goldar and Banerjee (2004) attempted to assess the impact of informal regulation of water pollution on water quality in Indian rivers. An econometric analysis of determinants of water quality of Indian rivers was carried out using water quality data for 106 monitoring points on 10 important rivers for five years. To explain variations in water quality, an Ordered Probit Model was applied, in which poll percentage in parliamentary elections, a proxy for the intensity of informal regulation, was taken as one of the main explanatory variables. Besides this, rainfall, industrialization, irrigation intensity and fertilizer use were some of the other explanatory variables used in the model to control for the influence of these factors. The river water quality was found positively correlated with rainfall and negatively correlated with industrialization, irrigation intensity and fertilizer use. A significant positive relationship was noted between poll percentage and water quality and
between rate of increase in literacy level in a district and water quality in rivers flowing through the district. Results pointed to a significant favorable effect of informal regulation of pollution on water quality in rivers in India.

Sekhar and Umamahesh (2004) used mass balance approach for the assessment of pollution load in the Krishna River, which is a typical receiving water body of both point, and non-point discharges. Comparison between upstream and downstream monitoring sites revealed changes in the concentration and load to the river. This information was used to discriminate between point and non-point source contribution to the river pollution. Further, pre- and post-monsoon water quality and flow data were also used to assess river pollution loads. The resulting differential loads, if adjusted for uncharacterized non-point source contribution may represent the total point loads to the river minus losses due to volatilization, sedimentation, adsorption and other physical, chemical and biological phenomena. The results of the mass balances indicated that non-point sources were major contributors to the pollutants loads.

Patel et al. (2004) work characterized and assessed the heavy metal content in different effluents and their relative availability in soils irrigated with effluent waters. Results of trace elements availability indicated that copper, lead, zinc and cadmium were the most available elements in different soils. They noted that soil continuously irrigated with wastewater had highest copper availability; moderate copper and cadmium availability and low iron. The relative availability of lead was highest in soil at the places where soil is irrigated by wastewater mixed with industrial effluent. They further found that zinc availability was greater in acidic soil. Among soil properties, organic carbon exhibited significant positive correlations with most trace elements and was the most influential parameter on metal availability, followed by soil pH and electrical conductance. Hence, it is concluded that high concentration of metals and physico-chemical characteristics in soil and sediment are attributed to industrial activities in nearby region.

Bhattacharyay et al. (2005) used the antennal deformities of Chironomid Larvae in bio-monitoring of heavy metal pollutants in the River Damodar of West Bengal. They noted presence of heavy metal pollutants like lead, zinc, copper, mercury and cadmium in the water after analyses of sediment and water. They found
that these metals are responsible for morphological deformities of antennae and other parts of chironomid larvae. They further noted that percentage of deformity was positive correlated with the concentration of lead in water and sediment ($r > 0.6$) at the confluence point. They have proposed a new severity index, SISS (antenna) to assess the deformity at the family of subfamily level.

Devi (2005) conducted a study to know the sources of pollution in the Nambul River, which is a most polluted river in Manipur. Physico-chemical analyses of major effluent points in the greater Imphal area were done to assess the level of pollution at major effluent points of river. They found these points responsible for collection of sewage and solid waste from in and around the greater Imphal area and poured it out into the Nambul River water. It was revealed that in the distance of 3 km where river is flowing through the heart of the city received the maximum loads of pollutant from various point sources. Hence, this stretch was the most polluted stretch of the river.

Singh et al. (2005) have applied multivariate statistical techniques such as cluster analysis (CA), factor analysis/principal component analysis (FA/PCA) and discriminant analysis (DA) to the data set of the Gomti River water quality and presented the usefulness of multivariate statistical techniques for evaluation and interpretation of large complex water quality data sets and apportionment of pollution sources/factors with a view to getting better information about the water quality and design of monitoring networks for effective management of water resources.

Tangri (2005) observed the impact of some industrial effluents on the River Pandu at Kanpur. He found that these industrial effluents contain various types of toxic heavy metals and have adversely affected the flora and fauna of river.

Naik et al. (2005) also attempted to study the physico-chemical characteristics of the Mahanadi River water at Sambalpur town to determine the pollution load because of the discharge of untreated sewage. They revealed that there was a sharp increase in values of TDS and hardness. They have described different methods to control the pollution. They reported considerably reduced suspended solid after sedimentation.
Kar et al. (2008) assessed the river surface water for heavy metal pollution and found the dominance of various metals in the following sequence: Fe > Mn > Ni > Cr > Pb > Zn > Cu > Cd. They have reported excess of heavy metal in river surface water and attributed it to the discharge of industrial effluents, municipal wastes, geology of riverbed and catchment area. Considering the status of heavy metal concentrations in water, it was concluded that the river water is not suitable for drinking and irrigational purposes due to the high concentrations of Fe, Pb and Ni and Mn respectively.

Parashar et al. (2008) studied the physico-chemical parameters of surface waters of two different sources and then put them to multivariate analysis to ascertain suitability for drinking purpose. They have reported variations in the water quality in all the examined physico-chemical constituents but water remains within the range of various agencies.

Yogendra and Puttaiah (2008) have also used WQI technique for overall assessment of the water quality in water body and found water unsuitable for domestic use due to high concentration of chlorides and sulphates.

Kumar and Dua (2009) used WQI technique to assess water quality of the river system and after comparing the WQI of three years of water they found that water was almost clear throughout the sampling period except for two or three months. High value of WQI supports aquatic fauna and flora.

Jindal and Sharma (2010) studied impact of sewage, industrial effluents and agricultural runoff on river water. They also related changes in physico-chemical and heavy metals parameters of river with seasonal variations.

Mahadev and Gholami (2010) reported the Cauvery River water quality within the desirable limit of WHO (1996). During the study, the river water was found safe for drinking, fishery, irrigation and industrial purposes as most of the parameters were found within the permissible limit.

2.2 GROUNDWATER

In present research work, groundwater quality was also analyzed and some similar attempts have been made in different parts of the country. In the groundwater
pollution studies the contribution of the following workers is also worth appreciating:

Tanwar (1981) concluded that increased use of fertilizers was responsible for increasing concentration of salts (such as chlorides and sulphates of calcium and magnesium) in well water. He also suggested some preventive measures otherwise; the groundwater pollution could become a serious problem.

Khan (2001) has also reported that industrial effluents discharged by the industries were the main source of contamination of surrounding groundwater. It was analyzed that the area at the vicinity of the river was most affected. He further observed that concentration of sodium and chloride is increased with proportional increase in total dissolved solids and electrical conductivity.

Rao et al. (2001) assessed the impact of industrial activities on migration of contaminant in groundwater. They found that discharged industrial effluents into open channels and streams were main sources of groundwater pollution. They found stream-aquifer interaction responsible for faster migration of contaminants in groundwater.

An attempt was made to bring out the nature and extent of arsenic problem in groundwater of West Bengal by Jain (2002). He found geological formations the probable source of arsenic in area groundwater. However, no definite explanation regarding the source of arsenic could be established so far.

Hussain and Hussain (2004) attempted to study the impact of textile industry wastewater on the groundwater that is used for irrigation purposes. High salinity was the major problem of the area and according to USSL classification based on SAR and EC, groundwater was found unsuitable for irrigation purposes.

Khurshid and Zaheerudin (2004) examined chemical characteristics of groundwater in parts of the Yamuna River sub-basin. They noted that majority of
samples were saline due to the presence of more clayey material with low permeability leading to longer residence time. They pointed out that discharge of untreated industrial wastewater in unlined drains, solid waste disposal in open fields and increased use of nitrogen and phosphate fertilizers were responsible for groundwater quality degradation in the area.

Garg and Totawait (2004) reports very high concentrations of zinc, chloride and sulphate in groundwater affected by the zinc smelter effluent carried stream. The study further indicated that water of wells situated in the vicinity of effluent stream were of medium salinity having higher values of calcium and magnesium and lower values of pH as compared to the water of the wells situated far away from the zinc effluent stream.

Mane et al. (2005) presented the study of water quality assessment of four different places in the Satara region, Maharashtra, based on the physical and chemical parameters. The study indicated that drought prone areas and sites exposed to domestic or municipal wastes were heavily polluted. It is concluded that fecal and non-fecal contamination, high dissolved solids, conductivity and salt content were main contributor of groundwater pollution in region. They noted that well waters were moderately poor in quality as compare to the hand pump water sources, which exhibited more metal and salt enrichments. The remote sites viz. springs and lakes, however, exhibited a better water quality in terms of optimum physico-chemical parameters and comparatively lesser fecal and non-fecal contamination. They have predicted that use of water for drinking or agricultural purposes from such wells and hand pumps without treatment may expose population to higher health risk.

Rajmohan and Elango (2005) calculated nutrient concentrations of phosphate and potassium to understand spatial and seasonal variations in the shallow subsurface of intensively irrigated region of the Palar and Cheyyar River basin. They found that agricultural activity such as fertilizer application; soil mineralization processes and irrigation return flow are major processes regulating groundwater nutrient chemistry in the region. It is reported that groundwater in the sedimentary formation had comparatively higher nutrient concentrations than hard rock formation groundwater, which seems due to nutrient adsorption by weathered rock matter. Seasonal water
level fluctuations showed that rising water level has increased groundwater nutrient concentrations due to agriculture activities.

Tripathy and Sahu (2005) confirmed the variation in groundwater hydrochemical parameters with change in season and found seawater intrusion another responsible factor for groundwater pollution. They have recommended that during pre-monsoon period, pumping from bore wells be minimized to control seawater intrusion.

Gowd (2005) did a case study to assess the groundwater quality for drinking and irrigational purposes of Peddavanka watershed, Anantapur District, Andhra Pradesh. He has reported that quality of groundwater is controlled by lithology, land use pattern and palaeo environmental conditions of the area. He further observed increase in groundwater TDS after rains because of dissolution of minerals from the overlying material by the infiltrating waters. He noted overall increase in all the parameters in post-monsoon season due to rock-water interaction and ruling out pollution from extraneous sources.

Haritash et al. (2008) found groundwater unfit for drinking purpose owing to a high concentration of calcium, magnesium, hardness and fluoride during their study on groundwater suitability of North Indian villages. Similarly, with respect to the agricultural use, it was found that most of the parameters had high value of sodium adsorption ratio (SAR), residual sodium carbonate (RSC), soluble sodium percentage (SSP) and magnesium hazard and waters from these sources were unsuitable for irrigation for long-term use. They have concluded that high concentrations of chemical constituents in groundwater are attributed to the lithologic composition of the area and recommended that this type of water should either be treated before the agricultural and drinking uses or be used intermittently.

Singh and Singh (2008) after conducting a study in Gwalior region concluded that groundwater water could be used for irrigation after primary treatment or filtration of samples that fall at higher side of the limit. They noted SAR and TDS values less than 10 and 1500 in the groundwater and found useful for irrigation. Based on the USSL classification, groundwater was found in two categories (i.e. C2-S1 and C3-S1), indicating low sodium hazards to crop and suitability for irrigation.

2.3 RESEARCH AREA RELATED WORK

In spite of some exhaustive studies on the groundwater resources of Punjab and Haryana including Ghaggar River Basin with respect to its groundwater conditions, there is limited literature available about the quality of surface water and groundwater resources along the Ghaggar River.

The technical report submitted by United Nations (UN, New York) under the UNDP (1985) describes the hydrogeology and water quality of the Ghaggar River basin in Punjab, Haryana and Rajasthan. The work was carried out under the project of surface and groundwater resources in which recommendations about artificial recharge and well construction has been made for the water resource development in the area. The report has also briefly described geology, climate and soil characteristics. Some conclusions based on mathematical modeling are also included. Central Pollution Control Board (CPCB Report, 1989) has analyzed water quality of the Indian rivers through National Water Quality Monitoring Programme (NWQMP) and found that some water bodies were not meeting the desired water quality criteria. In 2002 and 2004 also, CPCB intensively surveyed the polluted river stretches including the Ghaggar River stretches to know the sources of the pollution such as urban centers and industrial units with the help of State Pollution Control Boards (SPCBs) and found that the Ghaggar River was polluted. Punjab Pollution Control Board (PPCB Report, 1995) has monitored the four rivers of Punjab for the quality assessment of surface waters. The data analysis of limited monitoring sites indicates that the Ghaggar River is highly polluted near the confluence points of effluents from different sources. Punjab State Council for Science and Technology (PSCST Report, 2005) has reached at similar conclusion while working on the status of environment in Punjab.

Central Ground Water Board (CGWB Report, 2003) studied water resources of Punjab and Haryana and found that some districts of two states are affected by high fluoride contents. In another report (CGWB, 2003b), has monitored the groundwater
of Punjab for its quality and quantity. While working on trace elements concentrations, the pollution status of Amritsar, Ludhiana and Mandi Gobindgarh has been completed. Pollution due of iron, selenium and arsenic has been worked out. The department is regularly monitoring pre- and post-monsoon groundwater level to assess the amount of water recharge through precipitation and groundwater potential of the area. The following workers have also made notable contributions in this direction.

Pandit (1980) studied the hydro geochemical variations in groundwater with depth in the lower Ghaggar River basin. Tyagi and Rao (1986) discussed genesis of water logging and salinity in Ghaggar–Yamuna alluvial plains. They concluded that water logging and salinity problems are partly natural and partly man made. He reported the increase in deterioration of water quality with depth. The presence of saline water at shallow depth is related to hydro geological set up of the area.

Abrol and Mahajan (1982) monitored the quality of groundwater along the Ghaggar River and found medium to high Residual Sodium Carbonate (RSC) values and tolerable concentration of trace elements such as iron, fluoride, boron and nitrate. The study reveals the presence of the confined and unconfined aquifers adjoining the River Ghaggar.

Chaudhari and Gill (1984) demarcated three heavy metal mineral zones in the fluvial environment of the Ghaggar. They related heavy metal mineral assemblage to the source rocks, which are drained by the river. Dutt (1984) studied the geomorphology of a part of the Ghaggar River Basin by determining morphometric analysis of a badland area. He identified six major geomorphic units, which are grouped into two-mega unit’s viz. older alluvial surfaces and recent flood plains. The study exhibits southward shifting of the river course.

Bhatnagar and Garg (1997) studied the macrozoobenthic fauna at three stations along the River Ghaggar near Devigarh, Sirsa and Ottu and found that with increase in the influx of pollutants, an increase in values of biological oxygen demand and heavy metals concentrations occurred resulting in decrease of dissolved oxygen and macrozoobenthic fauna. They also correlated the factors influencing quality of surface water by multiple regression analysis (Bhatnagar and Garg, 1998a).
Bhatnagar and Garg (1998b) have conducted the environmental impact assessment study in the River Ghaggar in Haryana stretch based on physico-chemical characteristics and biotic community. It has been concluded that discharge of industrial effluents and sewage has altered the ecology of the river.

Radhakrishna and Merth (1999) while discussing the evolutionary history of the lost Vedic Sarasvati described the historical aspects of the River Ghaggar and its tributaries.

Kaur et al. (2000) carried out physico-chemical analysis of the Ghaggar River in the region of the Punjab and found that sites receiving both sewage and industrial discharge were maximum polluted.

Kaushik et al. (2000) studied the heavy metals concentrations in the water of the River Ghaggar and reported the occurrence of heavy metals in the river water more than that of recommended maximum permissible limit all along its route in Haryana. The trace metal pollution was observed to be higher in downstream direction due to substantial inputs coming from industrial, municipal and agricultural wastes.

Rathore (2003) has critically examined the proposed plan for Satluj-Ghaggar-Yamuna-Jojari-Luni-Sabarmati link channels. According to him, the floodwater of the Ghaggar River during rainy seasons can be diverted to the state of Rajasthan, which will get additional irrigation. Newly identified Ghaggar-Yamuna-Sabarmati link can be used to link the rivers of northern India to southern India. The linkage plan will make the western India largest food grain producing and irrigated area of the world.

Tripathi et al. (2004) have worked on geological constraints in the Ghaggar-Sarasvati hypothesis. They were of the view that the changes in the monsoon scenario after 3500 BC could have gradually dried up the Ghaggar River and resulted in migration and/or extinction of the Harpappan civilization on this river.