2. REVIEW OF LITERATURE

2.1 River water pollution

The undesirable change in physico-chemical characteristics of water bodies is water pollution. Today pollution of water resources has been most exploited due to increasing population, industrialization, urbanization, increasing living standards and board spheres of human activities. Good quality water is inadequate even for the normal living and is getting polluted due to industrial discharges including those of paper, textiles, rayon, fertilizers, pesticides, detergents, antibiotics, oil refineries, tannery and photo films.

Consequently water resources of highly industrialized cities in India (Such as Mumbai, Kolkata, Delhi, Kanpur, Pune, Agra, Durgapur etc.) have been chronically polluted. Thus, efforts are mainly concentrated to enact laws to check these practices to control water pollution.

Major Indian rivers, such as Ganga, Yamuna, Tapti, Narmada, Sone, Chambal, Daha, Damodar, Krishna, Cauvery and other rivers are severely polluted. Systematic observations at different distances of these rivers are being made by several researchers time to time.

The following important conclusions were drawn from the river water pollution

1. Water quality is deteriorated everywhere.
2. Rivers were severely polluted during the summer periods and minimum during the winter/monsoon.
3. The effect of effluents and discharge varies with the distance and nature.

4. Water resources contain toxic metals such as Hg and other chemicals such as ammonia, cyanide, organic matter etc. in different concentration.
5. Suspended solids, odour and turbidity get increased abruptly in rainy seasons.
6. Coliform content also increase up to 100 fold in the river water during monsoon.

2.2. Global river water pollution

River pollution becomes apparent at time during accidents though horrifying scene of dead fish floating on the surface of water. But more often, it exists as chronic and insidious pollution from different human activities. Pollution causes severe deterioration in the state of health of rivers across the entire planet.

Actually chronic river pollution, which is much more serious and originates from domestic, agriculture, industrial and mining operations, generally remains unnoticed till the malfunctioning of the systems become openly visible. Floating refuse, drifting corpses of dead fish and over bearing moss or algae are some of such malfunctioning of the system.

2.3 Water pollution in major rivers of India

The disposal of waste leads to contamination of rivers and lakes chronically affecting the flora and fauna. According to surveys carried out on selected stretches of important rivers, it has been found that most of the rivers are grossly polluted.

Ganga and Yamuna rivers are not alone that are highly polluted. Almost all the major rivers, such as Gomti, Damodar, Hooghly, Sone, Godavari, Cauvery, Periyar, Mahanadi and Kotjori Rivers have become giant sewers for the country’s urban population. The main sources of pollution of Gomti, near Lucknow in UP are paper and pulp mills and sewage.

Ganga River at Kanpur is highly polluted. The Kanpur city, with a population of more than 2 millions, exposed to industrial waste equivalent to domestic sewage load from a population of city, tanneries, textile miles, jute mills and a number of other chemical and other pharmaceutical mills.

The domestic sewage discharged from a population of about 2 millions gives rise to numerous water borne diseases, thereby affecting the human health and deteriorating the water quality.

Damodar River is polluted because of fertilizers, fly ash from steel mills, suspended coal particles from washeries and thermal power station. The Damodar valley from Durgapur to Asansol forms the largest industrial complex in West Bengal. The area contains two parts- Asansol- Raniganj region and Durgapur region. In Asansol- Raniganj region, iron and steel mills and Bengal paper mills discharge their waste in to the river. Durgapur steel plant also discharges its wastes in to the river through Singaron Nalah.

Hooghly at Kolkata is polluted due to power stations, paper and pulp mills, jute, textile and chemical mills, metal steel, varnishes, soap and a huge bulk of sewage.

The Cauvery river in Tamil Nadu gets polluted by sewage, tanneries, pulps and rayon mills. Periyar River in Kerala has been dammed at many points and caries effluents of many chemical industries. In Orissa, water from rivers Mahanadi and Kotjori are quite unfit for human consumption because of severe pollution. The Orissa high court has directed on March 1992 to the state Government to act immediately on the reports of the Pollution Control Board and take necessary action to prevent water pollution in Mahanadi and Kotjori rivers.

Yamuna River is an open sewer in Delhi. The water of Yamuna river is unfit even for irrigation, what to say of drinking, swimming, bathing and fisheries. It is highly polluted at Okhala industrial area. Discharge of effluents by large industries, medium and small industrial units pollute the water of Yamuna river. The large and medium industrial units constantly pour their toxic materials consisting of sodium salts, acids, alkalies, As, Hg, phenols, DDT, BHC, dyes etc in Yamuna river. Many small industrial units deteriorate the water quality by adding pollutants including oil, grease, toxic cyanides and hazardous chemicals in to river water.

In many countries water pollution is remedied by improving sanitary conditions and applying efficient techniques for water treatment. But this pollution is increasing at an alarming rate because even the engineers fail to apply biological treatment techniques which have been well known for forty years. The greatest need is, therefore, a more efficient administration and the use of best available technology.

2.4 Ganga Action Plan

Inertia in taking action to reduce the level of pollution stemmed largely from a widespread belief that the Ganga, as a holy river, had the ability to purify all that came into contact with it. Although there is some scientific evidence for the Ganga river's high capacity to assimilate (i.e. biodegrade) a large level of organic waste input, including pathogens, but no river can sustain its self-purifying power with this kind of over-use, misuse and abuse of its waters.

The Ganga Action Plan (GAP) originated from the personal intervention and interest of our late Prime Minister Mrs. Indira Gandhi who had directed the Central Board for the Prevention and Control of Water Pollution, now Central Pollution Control Board (CPCB) to do a comprehensive survey of the situation in 1979. CPCB published two comprehensive reports which formed the base for GAP in Oct 1984 but was not presented to the nation formally due to assassination of Smt. Indira Gandhi.

In Feb 1985, the Central Ganga Authority (CGA) with the PM as Chairman was formed, with an initial budget of Rs 350 crore to administer the cleaning of the Ganga and to restore it to pristine condition by our late PM Shri Rajiv Gandhi. In June 1985, the Ganga Project Directorate (GPD) was established as a wing of the Department of Environment. GAP was launched on June 14, 1986 by Late Shri Rajiv Gandhi at Varanasi.

The Ganga Action Plan (GAP) covered nearly 27 cities (6 in UP, 14 in Bihar, 17 in West Bengal). Government has established Ganga Project Directorate in 1985 as a wing of Ministry of Environment and Forest to co-ordinate the activities performed by the Action plan for restoring the quality of river Ganga.

GAP I was started in 1985 as a 100% centrally sponsored scheme. Under GAP I pollution abatement works were taken up in 25 class I towns. So far, 259 schemes in 25 towns of Uttarakhand, UP, Bihar and WB have been completed and Rs 451.70 crore spent under GAP I. A sewage treatment capacity of 865 mld has been created under the programme so far. GAP I has been declared complete on Mar. 31. 2000.

GAP I was extended to GAP II which was approved in phases from 1993 to 1996 covering 4 major tributaries of Ganga, namely, Yamuna, Gomti, Damodar and Mahananda.

This action plan covers pollution abatement works in 95 towns in 7 states along the polluted stretches of 4 rivers. The total approved cost of the action plan is Rs. 1498.86 crore, which was initially approved on 50:50 cost sharing basis between the Central and State governments.

Later, GAP II was merged with NRCP in Dec. 1996. NRCP was converted into a 100% centrally funded scheme on the pattern of GAP I in Nov. 1998. The land cost after Mar. 31, 1997 was however to be borne by the States.

The meeting of the NRCA held in Mar. 2001, it was decided to adopt an integrated approach for the river cleaning program and all future works would be shared on a 70 :30 basis between the Central and the State Governments. Of the State share, the share of the public shall be a minimum of 10% of the total cost.

2.5 Objectives of the Ganga Action Plan

The main objective of the Ganga Action Plan is to abate pollution and improve water quality. The GAP consists of the following important tasks.

1. Renovation of existing trunk sewers in order to prevent the outflow of sewage in to the river Ganga.
2. Construction of interceptors, drains and sewers to divert the flow of sewage and other liquid wastes away from the river.
3. Installation of Sewage Treatment Plants (STPs) with special attention on recovery of resources such as treated water for the purpose of irrigation and agriculture.
4. Low cost sanitation schemes in adjoining areas of the river.
5. To conserve biodiversity and develop an integrated river basin management approach.

6. Development of river front and aforestation on the banks on the banks of the river.
7. Prevention and control of industrial pollution, in co-operation with regulatory agencies and providing some other schemes.
8. Regular and continuous monitoring of water quality at several places.
9. Identification and management of waste from grossly polluting industries.
10. To conduct comprehensive research to further the objective
11. To gain experience for implementing similar river cleanup program in other polluted rivers in India.
12. Public participation and awareness.

At the time of launching, the main objective of GAP was to improve the water quality of Ganga to acceptable standards by preventing the pollution load reaching the river. However, as decided in a meeting of the Monitoring Committee in June 1987 under the Chairmanship of Prof MG K Menon, then Member, Planning Commission, the objective of GAP was recast as restoring the river water quality to the 'Bathing Class' standard which is as follows:

BOD	3 mg/l max
DO	5 mg/l min
Total Coliform MPN	10,000/100 ml
Faecal Coliform MPN	2,500/100 ml

2.6 Limitations of Ganga Action Plan

Notwithstanding the delay in completion of the program, the implementation of pollution abatement schemes has been by and large satisfactory. However, certain major limitations have surfaced which are as given below:

1. States particularly Bihar and UP are unable to provide timely and adequate funds for Operation and Maintenance (O&M) of assets created under GAP.
2. In Bihar, O&M has been grossly inadequate. The State Government has neither been able to provide funds nor the required power on a continuous basis for O&M of assets like STPs, pumping stations, crematoria etc. Thus, the operation of nearly all the assets has practically come to a halt.
3. The Operation and Maintenance of conveying sewers and intermediate pumping stations have been grossly neglected in UP. As a result, despite the facilities being available, raw sewage is still finding its way into the river at several places.
4. Erratic and poor availability of power for operating the pumping stations, STPs and crematoria is a major bottleneck in UP. Although, for such installations dedicated power supply had been provided for, this has not been adhered to by UPSEB. As a result, in the event of power failures, raw sewage finds its way into the river and the treatment plants are adversely affected.
5. The Operation and Maintenance of facilities like toilets and bathing ghats has been neglected in general by the local bodies. Local bodies have also failed in discharging other civic functions in GAP towns.

6. The stretch of the river from Farrukhabad to Varanasi in general and Kanpur in particular is very critical in terms of the availability of the minimum flow in the river. At Kanpur, the pollution load from both the municipal as well as industrial sources is significantly large and the dilution capacity of the river is severely limited. As a result, the desired improvement in the river water quality has not been achieved at Kanpur.
7. The organic pollution (which is indicated by BOD) reaching to the river was possible to minimize through the GAP. However, disposal of treated/untreated sewage only partly contributes towards the microbial pollution of the river. A large amount of this pollution is contributed by such activities as open defecation, cattle wallowing, mass bathing, garbage and carcass dumping.
8. The acceptance of electric crematoria has been slow in UP and Bihar. Due to non-availability of power and funds, these facilities are virtually defunct in UP and Bihar.

2.7 Ganga Action Plan in Kanpur

Because of high level of pollution, Kanpur was identified as a key player in the GAP activities. Approximately Rs.730 million was invested under GAP Phase I in Kanpur. The total sewage generated in Kanpur at the time of launching of the GAP was around 285 MLD (Million Litres per Day) out of which 162 MLD of sewage was tapped under GAP Phase-I and to sewage treatment plants. The objective of these plants was to treat this 162 MLD of domestic sewage and 9 MLD of tannery effluent generated from 175 tanneries and supply the treated wastewater to nearby villages to irrigate their farmlands. Four Intermediate pumping stations were built along the Ganga and all wastewater drains, or nallas, were intercepted and diverted to the pumping stations.

The pumping stations were to release the wastewater into a common waste pipe leading to the main pumping station, which filters out solid waste and then pumps the remaining wastewater into three sewage treatment plants. Two of these plants (5 MLD STP & 130 MLD STP) treat domestic wastewater, using sedimentation after aerobic treatment and anaerobic stabilization, and together have a capacity for 135 MLD.

Another treatment plant with a capacity of 36 MLD incorporated Dutch technology known as Upflow Anaerobic Sludge Blanket (UASB). It makes use of anaerobic bacteria to decompose the waste material and requires some amount of post-treatment. This plant is meant for treating the tannery effluent with the idea that the chromium and other heavy metals from this effluent should be recovered and recycled at the factory. Various other projects were undertaken as well, including cleaning the sewers, expansion of the sewer system, installation of electric crematoria and the installation of low cost sanitation systems.

After completion of GAP-I, the Central government came out with a report in 1995, making the tall claim that the Ganga had shown 70% improvement due to GAP.

The primary objective of GAP Phase II is to tap and treat 200 MLD of sewage that remained untreated in GAP Phase I.

The Ganga Action Plan Phase I have failed on key counts both quantitatively and qualitatively. By quantitative failure we mean, the failure to tap significantly the discharge of raw domestic sewage and raw tannery effluents from entering the river waters. By qualitative failure, we refer to failure of the treatment plants to treat the tannery effluent and sewage to the desired and safe levels.

There is very little flow during the dry weather. Ganga Barrage was commissioned in 2005. Ganga is allowed to enter Kanpur through just one gate during the lean period.

2.8 Namami Gange

Union Budget 2014-15 has taken cognizance of the substantial amount of money spent in the conservation and improvement of the Ganga, which has a very special place in a collective consciousness of this country. However, the efforts are not yielded desired results because of the lack of concerted efforts by all the stakeholders.

Accordingly, an Integrated Ganga Conservation Mission called "Namami Gange" has been proposed to be set up and a sum of Rs. 2,037 crores has been set aside for this purpose. In addition a sum of Rs. 100 crores has been allocated for developments of Ghats and beautification of River Fronts at Kedarnath, Haridwar, Kanpur, Varanasi, Allahabad, Patna and Delhi in the current financial year.

Accordingly, Namami Gange approaches Ganga Rejuvenation by consolidating the existing ongoing efforts and planning for a concrete action plan for future. The interventions at Ghats and River fronts will facilitate better citizen connect and set the tone for river centric urban planning process.

On a medium term basis, certain interventions both infrastructure and non-infrastructure need to be introduced to set the tone for implementation of long term vision as also take up so called "no regret" activities in the interim.

Following are proposed to be taken up under Namami Gange-

(i) Nirmal Dhara- ensuring sustainable municipal sewage management.

(ii) Nirmal Dhara-managing sewage from Rural Areas.

(iii) Nirmal Dhara-managing Industrial discharge.

(iv) Aviral Dhara.

(v) Ensuring ecological rejuvenation by conservation of aquatic life and biodiversity.

(vi) Promotion of Tourism and Shipping in a rational and sustainable manner.

(vii) Knowledge Management on Ganga through Ganga Knowledge Centre.

2.9 Previous research works on Ganga River at Kanpur

A lot of research works have been done on the physico-chemical parameters of the river Ganga. A series of research papers publishing the results of studies carried on Ganga river water at Kanpur was reviewed. During the several decades number of studies have been reported, which dealt with heavy metals in the sediments of the Ganga River.

The physico-chemical quality and pollution load in Ganga river water at Kanpur was studied. As per study the BOD was minimum in winter and maximum in summer. In rainy season it was found that river was alkaline in nature but it was further revealed that chloride range was beyond the limit. The study also concluded that increase in the pollution load of the river was mainly due to discharge of heavy organic waste and heavy metals in the industrial waste from tanneries in Kanpur. It was further found that BOD load was increasing to six thousand Kg per day due to the discharge of million gallons per day of industrial waste from tanneries, textile mills and several other industrial units in the Ganga River [Saxena *et al.* (1966)].

Pahwa & Mehrotra *(*1966) studied the Hydro biological features of the river Ganga of approx 1090 km ranging from west in Kanpur to east in Rajmahal situated in Jharkhand. They reported that the value of pH of the river water was minimum during June to August and maximum during January to May. It was further revealed that in January and February the dissolved oxygen, i.e. DO was having maximum values & minimum values in monsoon season.

Prasad Kashi (1977) in his investigation reported some improvement in water quality parameters such as BOD, DO, Total Phosphate and Nitrate as compared to the previous study done by Saxena *et al.*

In the observation Bhargava, D.S. (1977) found that despite high organic pollution load in river Ganga, the Dissolved Oxygen level in the river was high and BOD level in the river was low. To partially explain this curious phenomenon, he invoked the bio-flocculation mechanism, which might result in flocculation and settlement of particulate BOD to river bottom.

Pandey *et al.* (1980) carried out physico-chemical monitoring of River Ganga at Kanpur at interval of one month for the year 1977. Nine sampling stations were selected on the basis of their importance. The analysis was carried out for the parameters BOD, COD, DO, temperature, ammonical and albuminoid nitrogen, sulfide, chromium, pH, sulfite, sulfate, chloride, hardness, electrical conditions, and total solids. The total effluents flowing into the River Ganga while passing through Kanpur were well above the assimilation capacity of the river during summer and winter months. Thus the vital values associated with the stream had almost been nullified.

In a survey it was found that quality index of water was far beyond the prescribed limit for the total length of water stretch in river Ganga at Kanpur. The research further revealed that the Ganga water has the capacity in bringing down the BOD, because of having the capacity of fast regenerating due to presence of well adopted micro-organisms in the river. Ganga water was rich in polymers which were due to excretion by various species of bacteria. The turbidity was removed by coagulation due to these polymers which were excellent coagulants and help in setting the suspended particles present in water at the sewage discharge point. [Bhargava, D. S. (1982)]

The heavy metals in the sediments and water of the Ganga River have been studied. The concentrations of cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead and zinc in the water and sediments of the Ganges river were determined by Atomic Absorption Spectro photometry in the year 1987. The respective ranges of concentrations of cadmium, cobalt, chromium, copper, iron, manganese, nickel, lead and zinc were found in the water and in the sediments. The data showed that there was considerable variation in the elements from one sampling station to the other [Ajmal, M. *et al*. (1987)].

Samples were collected at locations where the Ganga River entered Kanpur (up-stream, U/S) and left Kanpur (down-stream, D/S). Kanpur, one of the largest industrial cities located on the bank of the river Ganges, discharges large quantities of industrial effluents into it. Heavy metals (Cu, Cr, Fe, Pb, Mn, Ni, and Zn) were monitored monthly from July 1986 to June 1989. Time series analysis was carried out using a moving average model to estimate the trend values free from auto-correlation.

The two independent and identically distributed deseasonalized series for up-stream and down-stream were compared by the Analysis of Variance technique (ANOVA) to find out the space and time effect of different metal levels in the Ganges water. The measured and trend values were completely in accordance with the observed pattern. Significant site-related effects were observed from chromium due to the presence of a large number of industrial establishments, particularly tanneries, electroplating and metal processing industries. A time-of-year-related effect on the levels of nickel, copper, zinc, and lead were observed. These differences might be attributed to drought and other natural events. [Garg Nikhil *et al*. (1992)].

The leather industry, besides being a major contributor to the Indian national economy, is unfortunately also one of the major polluters. The present article discusses the influence of the wastes on the physicochemical characteristics of the Ganga water and sediments. Two sampling sites have been chosen at Kanpur, the first before and the second after the point where tanneries are located. The same physicochemical parameters which have been determined in the wastes have been monitored at these two sites for two seasons. The results reveal that most parameters increase as the river traverses between these two points. The increase in values of parameters such as BOD, COD, Cl^- and total solids could be due to the domestic wastes just as much as to the tannery wastes. Phenols and sulfides can also come from other sources, but their probability of coming from tanneries is higher. However, chromium is one parameter which can primarily be identified to originate from the tanneries. The speciation of the sediments for chromium revealed that the leakage of chromium into the Ganga is taking place at the second site. There is almost a ten folds increase in chromium at the second site as compared to the first. At the first site the surface chromium is primarily in the residual fraction while at the second site it is in the Fe–Mn oxide fractions.

After doing detailed analysis of upstream and downstream water and sediment revealed that there was increase of ten-folds in chromium level in the sediment collected from downstream Jajmau area of Kanpur due to unchecked release of untreated tannery effluent into the Ganga River. [Khwaja, A. R *et al*. (1992)]

A study with seasonal variation in water quality of Ganga River at Kanpur city during July 2002 and June 2004 was done. The samples were collected from three different sites viz. Bithoor, Bhairoghat and Jajmau. Various physico-chemical parameters such as temperature, Turbidity, Transparency, pH, Alkalinity, Hardness, Chloride, Phosphate, BOD, COD were analyzed. The pollution level of river water increased as from site I i.e. Bithoor to site II i.e. Bhairoghat and site III i.e. Jajmau. Significant seasonal variation in the physico- chemical parameters was observed during the study. The analyses of river water at various sites revealed that the pollution level increases as from Bithoor to Jajmau. The water of the river Ganga at Kanpur should not be used for drinking purposes unless it is treated. The pH values indicated the alkaline nature of the river. High values were recorded at the site when industrial effluent was discharged into the river. [Zafer, A. and Sultana, N. (2007)]

Singh, M. *et.al.*((2002) in the investigation, they have attempted to quantify the impact of urbanization activities on the stream sediment quality taking into consideration a number of important urban centres of the Ganga Plain. Stream sediments from six urban centres of the Ganga Plain were analyzed for heavy metals concentrations like Cr, Mn, Fe, Co, Ni, Cu, Zn, Pb and Cd. The finding indicated that the stream sediments and urbanization activities had a controlling influence on the accumulation and transportation of anthropogenically originated toxic heavy metals in the rivers of the sacred Ganga Plain.

Metal enrichment factors of Cr, Ni, Cu, Zn, Pb and Cd had indicated that these urban centers act as anthropogenic source of heavy metal inputs into rivers of the Ganga Plain.

As a result of the increasing anthropogenic activities in the gangetic plain, Ganga water quantity as well as quality has declined over the years. A major effort to clean Ganga, named Ganga Action Plan (GAP) was instituted by the Government of India in 1984. The emphasis in GAP was on the reduction of organic load on the river through interception, diversion and treatment of wastewater reaching the river, thus maintaining the biochemical oxygen demand (BOD) and dissolved oxygen (DO) levels of river within the acceptable limits. A major criticism of GAP is that the significance of river ecology has not been addressed adequately during its conception and implementation. One of the important aspects from this perspective is the photosynthetic activity in the river Ganga. It has been postulated that photosynthetic activity plays an important role in maintaining high levels of DO in Ganga, and as a result the river can assimilate high organic loads without appreciable depletion in dissolved oxygen levels. Objective of the present study was to assess the photosynthetic activity and oxygen production rates in the river and correlate these values with various water quality parameters. Most polluted stretch of Ganga, which is known as the Kannauj–Kanpur stretch was chosen for this study. Based on the results of the study, it was concluded that despite implementation of phase I of GAP and consequent diversion and reduction of organic loading to the river, both BOD and DO levels in the river has increased in the entire Kannauj –Kanpur stretch, except at Jajmau, where anaerobically treated effluent is discharged to the river. The nitrogen levels have also increased in the entire Kannauj–Kanpur stretch. Dissolved oxygen (DO) and alkalinity in the river water vary diurnally at all sites.

Chlorophyll-a levels and oxygen production rates due to photosynthesis appear to be positively influenced by phosphate levels in the river water. Chlorophyll-a, levels appear to be negatively correlated to the ammonical and total Kjeldahl Nitrogen (TKN) content in the river water, suggesting the possibility of release of nutrients due to algal death and decomposition under certain circumstances. [Tare, V. *et al* (2003)]

Kunwar, P. Singh *et al.* (2004) were studied to assess the impact of waste water/ sludge disposal (metals and pesticides) from the sewage treatment plants (STPs) in Jajmau, Kanpur (5 MLD) and Dinapur, Varanasi (80 MLD), on health, agriculture and environmental quality in the receiving/application areas around the industrial city Kanpur and Varanasi in Uttar Pradesh, India. The raw samples , treated and mixed treated urban waste water samples were all collected from the inlet and outlet points of the plants during peak (morning and evening) and non-peak (noon) hours. They found that the STPs sludge had both positive as well negative impacts because it was enriched with high levels of toxic heavy metals and pesticides and also with several useful ingredients such as N, P, and K providing the great fertilizer value. The STPs sludge studied here had cadmium, chromium and nickel levels above their tolerance levels as prescribed for agricultural land application.

The objective of study was the sediment quality assessment of Ganga River at Kanpur city where effluents from tannery industries are discharged. Sediment samples from upstream and downstream area were collected and analyzed for trace metals and toxicity bioassay. Among various trace metals examined Cr in downstream sediment was 30-fold higher than in upstream sediment and its concentration was above the probable effect level. In general trace metals in the downstream sediment were found higher compared to report earlier.

Seed germination bioassay revealed negligible effect on the growth of root but the shoot growth was stunted in seeds exposed to downstream sediments. Trace metals determined in sediment elutriate showed poor elution of metals in aqueous phase but elutriates exerted toxic effects on both root and shoot growth, suggesting presence of other bio-available toxic factor associated with sediment. The study revealed that seed germination bioassay may be used to differentiate contaminated and uncontaminated sediment. [Beg, K. R. and Ali, S. (2000)]

The study inventoried the presence of heavy metals in the samples collected from two areas of Industrial city Kanpur namely Panki and Jajmau. The bulk concentration of heavy metals found in solid waste samples were Fe , Mn , Zn , Cu , Cd , Ni Pb and, Cr, respectively. The heavy metal pollution which was so detected indicated contamination in surface water and also in food chain. This has raised great concern pertaining to adverse consequences to environment and human health. [Rawat, Manju *et al*. (2009)]

Trivedi, Priyanka *et al*. (2010) studied various physico-chemical parameters i.e. turbidity, temperature, pH, total hardness, iron, chlorides, dissolved Solids, calcium, sulphate, nitrate, fluoride, chromium, total alkalinity for various seasons; Summer, Monsoon, Autumn, Winter, Spring for the period (April-December- 2008 and (January- March-2009) in the surface water, ground water and filtration plant treated water of Kanpur city. Significant variations of physico-chemical parameters of surface water were observed.

Various physico-chemical parameters for the water samples were within highest desirable limit (HDL) prescribed by WHO for drinking purposes for all seasons except for pH in summer, Total alkalinity and Fe contents in spring, autumn and winter; Total dissolved solids in winter, Turbidity in all seasons. The observations imply that Ganga water in monsoon is better than winter seasons, where as the ground water was found better in winter compared to that of summer season. The results suggest that the quality of surface water improved after treatment in filtration plant as compared to ground water.

Srinivasan e*t al.* (2010) found out the extent of chemical pollution in soil due to industrial waste. This was done around Jajmau (Kanpur) and Unnao industrial areas (80°15'–80°34'E longitude and 26°24'–26°35'N latitude), of Uttar Pradesh. These two cities are prominent centres for leather processing clusters of tannery industries along the banks of river religious Ganga, besides other industries. The results of this study have shown the impact of anthropogenic agents on abundances of heavy metals in soils in the area studied. The soil is extremely contaminated due to many years of random and frequent dumping of hazardous waste material and free discharge of effluents by various industries like cotton and wool textile mills, tanning and leather manufacturing industries, huge fertilizer factories and a number of arms factories. High content of toxic metals in the environment resulted in an increase in their content in ground waters which was a result of leaching. The detected levels of total metal contamination in several samples were found to exceed the international threshold values.

Increased concentration of Cr and Zn obtained in the soil of the research area indicated that the pollution of these hazardous metals originated basically from the industries of that area, either from dumping of industrial waste or from release of uncontrolled effluents on to the ground which resulted in great contamination of the water bodies and streams present in the area of study.

Khare, Richa *et al.* (2011) studied physico-chemical parameters of water samples collected from different locations of Ganga river at Kanpur city of U.P, India. The water samples were collected during pre monsoon season of 2010 in order to calculate highly correlated & interrelated water quality parameters. The correlation coefficient was calculated & its significance was checked by t-test. The results of different physico-chemical analysis like total hardness, temperature, pH, turbidity, suspended solids, oxygen consumption were compared with WHO standards. It was found that all physico-chemical parameters were within the highest desirable or maximum permissible limit set by WHO during pre-monsoon, monsoon & post-monsoon seasons. The value of F^-, Cl^- & NO_3^- was lesser than WHO prescribed limit while turbidity value was higher.

The river Ganga, in Kanpur takes entry at Bithoor and passing along several ghats and lakes it exit at Jajmau covering a distance about 22 Km. For a study purpose a stretch of river Ganga is selected for the upper stream near Bithoor, middle stream to the Permat ghat and to the downstream near Jajmau up to new Jajmau Bridge at Kanpur. The physico-chemical analysis of the collected water samples from upper, middle and down streams of river Ganga from tannery area to Jajmau automobile Transport Bridge revealed that almost all the major characteristics were little beyond permissible limits.

The water as such could not be used both for drinking and bathing purposes. It could only be used for irrigation in fields but after treatment. The low values of dissolved oxygen affected potability of water and caused mortality of fish and other aquatic animals in Bithoor, Permat and Jajmau, respectively. The high percentage of cadmium caused vomiting, diarrhea, abdominal pain, giddiness, bone deformation, hypertension, choking, coughing and bronchitis to resident of the people residing in that areas particularly in Jajmau. The high percentage of chromium also caused mortality and low longevity of the aquatic organisms particularly fishes. The high MPN values and BOD values also indicated the organic pollution in the Bithoor, Permat and Jajmau region. The result of turbidity showed that water was very dirty near Jajmau region because it is the entry point of the tannery effluents discharged in the river Ganga while the water of Permat and Bithoor zone is not so dirty because it is diluting during the course of its movement, but it could not be recommended for animals and human beings before treatment. The water in the Bithoor region could be used for bathing and agriculture as such but could also be used for drinking purpose after treatment. [Johari, Reeta *et al*. (2011)]

An investigation has been made to ascertain the effect of tannery effluent associated with seasonal variation on river water samples collected from confluence point, upstream and downstream located near Jajmau area at Kanpur, U.P. All the samples analyzed for physico-chemical parameters including estimation of chromium. The pH at confluence point (Q) was significant alkaline during summer as compared to upstream point due to dumping of untreated tanneries effluent, which suggested that utilization of salts for leather tanning process. Study showed that a significant decrease in DO values at summer, although the higher level of DO during monsoon season might be attributed to the dilution of the effluent by rain water.

The level of BOD showed a significant increase at confluence point during as compared to upstream point during summer. Although the level of COD at different sampling points affected with seasonal variation but it was not significant. However this study also revealed a significant negative correlation showing that as BOD and COD increases in values DO decreases. The correlation analysis of TDS versus BOD and COD gives a positive correlation showing that as TDS increase BOD and COD also increases. Theses correlation analysis shows that levels of TDS, BOD and COD are highly correlated with each other in sampling area during different seasonal variation. Chromium levels were high in almost all sampling points with seasonal variation, thus tanneries effluent with seasonal variation showed highly adverse effect on river Ganga. [katiyar, Shashwat (2011)].

Trivedi, Priyanka *et al.* (2009) investigated on physico-chemical parameters of water samples collected from the different sampling stations i.e. Ghats of Kanpur and its nearby areas of Ganga River. To identify the highly correlated and interrelated water quality parameters, Correlation coefficients were calculated between different parameters and for checking the significance t-test was applied. The World Health Organization (WHO) recommended values was compared by the obtained values found in samples of different physico-chemical parameters i.e. turbidity, Total hardness pH, temperature, Iron, consumption, total alkalinity, Oxygen, Suspended solids. It was found that significant positive correlation holds for TA with Cl^-, Mg^{+2}, Ca^{+2}, TH, TDS and fluoride. A significant negative correlation was found between SS with chloride, Mg+2, TDS and fluoride. All the physico-chemical parameters obtained from the samples collected before premonsoon, monsoon and after monsoon seasons are on the higher side or maximum permissible limit as recommended by WHO, while NO_3^- , Chloride and F^- are less than the values recommended by WHO.

A study reported that the water of Ganga river is found to be polluted in respect to analyzed Parameters. Ganga is dying both physically and biologically. The water in Ganga River throughout the city, from Bithoor to Dhori Ghat is fast losing its individuality. The source of pollution in the river is sewage effluents that have considerably spoiled the quality of its water in this stretch of the river. At Siddhnath Ghat, river is highly polluted because of solid waste generated in tanning process and tannery effluent discharge in to the river as compared to other Ghats. [Arya, Sandeep *et al*. (2013)]

Impact of effluents discharged in Ganga through various sources on chemical composition and level of heavy metals was studied at Kanpur and Varanasi. The effluents were found to be nil in oxygen with acidic in oxygen with acidic to neutral pH and having very high values of free CO_2, alkalinity, conductance, total dissolved solids, hardness, chloride, organic matter and BOD load. The heavy metals Cu, Cr, Cd, Pb and Zn were also quite high in the effluents. The discharged effluents induced severe reduction in oxygen and sharp increase in the level of free CO_2, alkalinity, conductance, total dissolved solids, hardness, chloride, organic matter and BOD load at the discharge point from their comparatively much lower values before discharge. The level of Cu, Cr, Cd, Pb and Zn also showed higher values at the discharged point. Considerable improvement was observed below the discharge (BOF zone). The present observations made at Kanpur and Varanasi stretch of Ganga was a strong pointer towards the possibility of ecological up-gradation and thereby enhancing the aquatic productivity in our river system through regulated effluent flow. The measures taken so far seem to be inadequate and more effective measures should be taken to bring the river back to their original status. [Kumar, Amit (2009)]

Theraja *et al.* (2011) collected Water samples from Jalsansthan Benajhawar Kanpur sampling station on the Ganga River with in Kanpur city in the year 2008 (April) -2009 (March) and analyzed for 14 water quality variables (physico-chemical) parameters. The data obtained were standardized and subjected to Principal Components Analysis (PCA) to define the parameters responsible for the main variability in water quality variance for Ganga River with in Kanpur city. The PCA produced two significant main components and explain more than 99.316% of the variance namely, anthropogenic effect and industrial effect; that represent 64.470% and 34.846% respectively of the total variance of water quality in Ganga River. Results revealed that Total dissolved Solids, Total Alkalinity, Total Hardness were the parameters that are most important in assessing variations of water quality in October, November, December, January, February, March, April (post-monsoon season) in the river. Results also revealed turbidity, suspended solid were the parameters that are most important in assessing variations of water quality in June, July , August and September in the river (monsoon season). The study suggested that PCA technique is useful tool for identification of important river water quality monitoring months and parameters. Ca^{+2}, Cl^{-}, SO_4^{-2},Temperature, Fluoride, pH, Fe, Oxygen Consumption(OC), Cl^{-}, Mg^{+2} are found to be non principal water quality parameters.

2.10 Previous research works on Ganga River in other cities in India

A number of investigations have been carried out on the physico-chemical characters of the Ganga River in Varanasi, Haridwar, Bhagalpur, Patna etc. Researchers published a series of papers reporting the results of studies carried out at Varanasi and other cities during past several decades.

Ekin Birol A, Das, Sukanya (2010) adopted a stated preference environmental valuation technique, which is called the choice experiment method in order to estimate local public's willingness to pay (WTP) for improvements in the capacity and technology of a sewage treatment plant (STP) in Chandernagore municipality. This is located on the banks of River Ganga which is in India. A pilot choice experiment study was administered to 150 residents of Chandernagore which were randomly selected. The data was analyzed using the conditional log it model with interactions. The results of analysis had revealed that residents of this municipality were inclined to pay significant amounts in way of higher monthly municipality taxes to make sure that the full capacity of the STP used for primary treatment. The technology was upgraded so that secondary treatment could be done. Overall, the results reported support the increased investments so as to improve the capacity and technology of STPs. This was in order to reduce water pollution followed by environmental and health risks which are currently a threat to the sustainability of the country's economic, cultural and religious values which this sacred river generates.

Mehrotra, M. N *et al.* (1990) in their study revealed that pollution of the Ganga river in Varanasi city is due to the domestic sewage effluents & mercury, lead, chromium and nickel in the sediments of Ganga river at Varanasi due to the several polluting industries, burning of dead bodies at the ghats, use of detergents, as well as insecticides and pesticides used in agriculture.

Tripathi, B.D *et al.* (1991) in their study analyzed the variation of physico-chemical characteristics of Ganga water in Varanasi at different points during the different months of the year.

Here six ghats viz, Shiwala ghat, Rajendra Prasad ghat, Rajghat, Chauki ghat, Assi ghat & Harischandra ghat were chosen for analysis of physico-chemical parameter such as pH, acidity, alkalinity, biological oxygen demand dissolved oxygen, chemical oxygen demand, chloride, electrical conductance, nitrate and phosphate. When variance analysis was carried out, it was found that the physico-chemical parameters vary with variation in month and site. The concentration of sewage discharged in May & June was found to be higher by Duncan's multiple-range test. Most concentrated sewage with the highest pollution load was found at Rajghat, whereas at Assighat, least concentrated sewage was found.

The study was carried out for a period of only two seasons (Premonsoon and Post-monsoon) in a year. The physico-chemical parameters such as pH, electrical conductivity (EC), alkalinity, total solids (TS), hardness, chloride, dissolved oxygen (DO), biological oxygen demand (BOD) & most probable number (MPN) were evaluated at selected sites of River Ganga. The river is subjected to severe domestic and sewage pollution at two selected sites of Patna. At sampling site I and II physico-chemical parameters were not found to be within the safe limits of drinking water as World Health Organization WHO (1984). But at sampling site II chloride were found within the safe limits. At sites I & II water sample was not found good quality showing that the River Ganga has moderately polluted. The present studies indicate that increase water pollution levels in the River Ganga present near urban environment due to discharge of various types of waste water/ sewage/ effluents. [Rai, Arvind Kumar *et al*. (2011)]

Singh, Namrata (2010) studied the effect of pollution in water at different ghats of river Ganga at Varanasi.

This Ganga river basin was not having anthropocentric activities till 1940. But after Indian Independence in 1947 the agricultural, industrial and sewage wastes were dumped in river Ganga. The water quality of river degraded due to various developmental activities &population explosion in Ganga basin of this area. From six different ghats viz. shiwala ghat, Raj ghat, Assi ghat, Rajendra Prasad ghat, Harischandra ghat & Chauki Ghat waste water samples were collected & physico-chemical properties viz. DO, BOD, COD, chloride, temperature, electrical conductance, pH, alkalinity, acidity, phosphate, nitrate & chloride was analyzed. In the study shiwala ghat was found to be least polluted & Rajghat was the most polluted one.

The study of Kumari, M. *et al.* (2013) revealed that Ganga water in Varanasi is polluted in respect of analyzed Physico-chemical parameters. At different discharge points of river Ganga in Varanasi the industrial effluent mixed with municipal sewage is discharged. Six sampling stations were selected for analysis of biochemical oxygen demand, electrical conductivity, chemical oxygen demand, pH, total acidity, temperature, Total alkalinity, nitrate nitrogen, dissolved oxygen, phosphate, lead, Zinc, iron, nickel, chromium, cadmium and copper. The metal Cr & EC had smallest value which revealed a relationship between the parameters. This was confirmed by Pearson’s correlation. Based on proximity distances, EC, Cr, Ni, Fe, N, COD, temperature, BOD, and total acidity comprised one group; Zn, Pb, Cd, Total alkalinity, Cu, and phosphate were in another group. DO and pH formed a separate group. These groups were confirmed by Pearson's correlation (r) values that indicated significant and positive correlation between variables in the same group. Box-whisker plots revealed the pollutants concentration increases while going downstream and maximum at the downstream station Raj Ghat and minimum at the upstream station Samane Ghat.

Seasonal variations in water quality parameters signified that total alkalinity, total acidity, DO, BOD, COD, N, phosphate , Cu, Cd, Cr, Ni, Fe, Pb, and Zn were the highest in summer and the lowest during monsoon season. Temperature was the highest in summer and the lowest in winter. DO was the highest in winter and the lowest in summer season.

Singh, A. K., *et al.* (2009) carried out the study of physico-chemical parameters of Ganga river water at Varanasi for a period of two successive years (2003-2004) which exhibited significant variations. Maximum water temperature was recorded in June and minimum, in January. The pH value of river water ranged between 7.5 and 8.9. It was lowest in December and January but was within the alkaline range exhibiting narrow fluctuation. Dissolved oxygen value was high during winter and low in monsoon. The seasonal fluctuation in free CO_2 was found maximum during monsoon and minimum in summer. A wide range of variation in chloride contents was recorded; lower during monsoon and higher in winter and summer.

Rai *et al.* (2011) had observed that the general characteristics of water from the study area of River Ganges at Patna was alkaline in nature with more total solids as well as above saturated with dissolved oxygen. At sampling sites physico-chemical parameters were not found to be within the safe limits of drinking water as World Health Organization WHO (1984). At sites water sample was not found of good quality showing that the River Ganga had moderately polluted. In addition to some selected parameters were slightly higher limits prescribed by (WHO, 1984) and not tolerable for household and commercial purposes. Slightly higher hardness, a BOD and MPN value in Ganga river water was unfit for drinking purpose at selected sites.

However, high pH, TS, Hardness, BOD and MPN values suggested purification might be necessary for domestic consumption. Strict legal action should be taken against those who contaminate the River Ganga by waste dumping or discharges of local effluents.

Joshi, Dhirendra Mohan *et al.* (2009) investigated the physico-chemical parameters of Ganga river water in Haridwar (Uttarakhand). Systematic calculation of correlation coefficient between water quality parameters had been done with the objective of minimizing the complexity and dimensionality of large set of data. The significant correlation had been further verified by using t-test. The water samples were collected and analyzed for two consecutive years 2007 and 2008 from five sampling stations during three seasons (winter, summer and rainy). In the present study, an appreciable significant positive correlation was found for Free CO_2 with Cl- , TDSD, TSSD; turbidity with Cl^-, EC, TSSD, Cl^- with EC, Free CO_2, TSSD, EC with Cl^- , TDSD, TSSD. A significant negative correlation was found for DO with Free CO_2, COD, and turbidity, Cl^-, EC, TDSD and TSSD.

In order to analyze the physico-chemical parameters and to assess the water quality index of river Ganga at Haridwar by Joshi, Dhirendra Mohan *et.al.* (2009), water samples from five sampling stations were collected. The study had been divided into three seasons as summer (March to June), Rainy (July to October) & winter (November to February). The collection and analysis of samples was done for two consecutive years 2007 and 2008. The analytical data of various physico-chemical parameters indicate that some data like pH, electrical conductivity, total suspended solids, total dissolved solids, sodium and Turbidity were more than the prescribed limit in water samples collected from study areas.

Due to presence of high value of dissolved solids and sodium, water samples at some sampling station were found to be unfit for drinking purpose. The study revealed that water quality was better in 2007 than in 2008. In order to improve the water quality certain suggestions were given.

Joshi, Dhirendra Mohan (2009) attempted to analyze the water quality of river Ganga in Haridwar district for irrigation purpose. Water samples were collected from 5 sampling stations. The study area has been divided into three seasons: winter, summer and rainy. Water quality variables were measured in the river over a period of two years. The samples were analyzed for electrical conductivity, total dissolved salts, magnesium content, sodium percent, sodium adsorption ratio, residual sodium carbonate and permeability index (PI). Study of all these characteristics indicated that river water in rainy season was not suitable for irrigation purpose because of high values of total dissolved salts, EC and S P.

Kar, D. *et al*. (2005) concluded on surface water samples collected from the river Ganga in West Bengal. A total of 96 water samples were analyzed for pH, Cd, Cr, Pb, Ni, EC, Fe, Mn, Zn, and Cu. The pH was found to be in the alkaline nature whereas conductance was low. More than 92% of the analyzed samples contained Pb, Fe, Mn, Zn, Ni and Cr. Cd metal was detected in only 20 samples whereas Cu was detected only in 36 samples. Seasonal variation was observed and was significant for Fe, Mn, Cd and Cr.

The following pattern was observed:

Maximum mean concentration of Fe: observed in summer.

Maximum mean concentration of Mn: observed in monsoon.

Maximum mean concentration of Cd: observed in winter.

Maximum mean concentration of Cr: observed in winter.

Apart from variation with seasonal conditions, sampling location also had an effect on the concentrations for Fe, Mn and Cd. The analysis showed that Palta had the highest mean concentrations (mg/L) for Fe, Zn and Cu. The maximum mean concentration for Mn and Ni were recorded at Berhampore, while the maximum value of Pb and Cr were obtained at the downstream station, Uluberia. In the analysis the concentrations for the heavy metals were observed to be in the following order Fe > Mn > Ni > Cr > Pb > Zn > Cu > Cd. A significant positive correlation was exhibited for conductivity with Cd and Cr of water but Mn exhibited a negative correlation with conductivity.

Tiwari, R. K *et al.* (2005) studied to evaluate the impact of sewage pollution on the water quality of Ganga river in adjoining areas of Patna. To study the parameters of BOD, TDS, COD, TSS water samples were collected from the outfall drains to the river. It was observed that in drain water faecal coli form (MPN) was high. The Ganga river water shows high TDS, TSS, BOD, and COD during physico-chemical analysis of the water. All the physico-chemical parameters analyzed were found high across the bank as compared to the water in the middle stream of that sampling station. It was further revealed in the study that due to direct discharge of untreated sewage into Ganga, the quality of Ganga water has been severely deteriorated and the naturality of the Ganga water is being lost.

The Pollution of aquatic ecosystem by heavy metals has assumed serious proportions due to their toxicity and accumulative behaviour. This paper dealt with the measurement of five heavy metals i.e. Cu, Cr, Zn, Ni and Cd.

Grab samples of water and sediments for a period of two year (January 2007–December 2008) were collected from 3 different sites following the Standard Methods. Water and sediment samples of the river were processed and analyzed for heavy metals using AAS. The heavy metals found in the river water were Cu, Cr, Ni, and Zn. Some physico-chemical parameters viz, pH, dissolved oxygen, total hardness, phosphate-phosphorous and nitrate-nitrogen were also estimated as they had direct or indirect influence on incidence, transport and speciation of the heavy metals. Based on the findings, the Ganga river sediments from Champanala to Barari could be considered as unpolluted with respect to Cd, Cu, and Ni, whereas concentration of Cr and Zn show their pollutional status which might be detrimental to the rich biodiversity of the river segment by Singh *et.al.*(2012).

The physico-chemical properties of the water of river Ganga were studied at five different sites viz, site Ist – Patthar Ghat, site IInd – Bada Mahadeva Ghat, site IIIrd – Dadari Ghat, site IVth – Collector Ghat, site Vth – Chitnath Ghat during September 2005 to August 2007 river Ganga at Ghazipur, U.P. The depletion in DO and increase in temperature, TA, TH, calcium, phosphate, nitrate, sodium and potassium was observed. Variation in the value of different parameters was noticed according to season. Seasonally the values of TH were high in summer which gradually decreases in rainy and winter. The value of DO was highest in winter season and lower in summer while intermediate value was recorded in rainy season. The low value of DO during summer was due higher temperature and higher rate of microbial decomposition of organic matter. The values of BOD were highest in summer followed by rainy and winter season. The same trend of variation was also found for COD. [Yadav, R. C. *et al*. (2011)]

Over the years the river Ganga has been subject to tremendous pressure due to untreated sewage and industrial effluents being dumped in to the river at numerous places and the residues of pesticides and insecticides used in the farms are washed in to it. In the study, water samples from river Ganga were monitored for pH, dissolved oxygen, total hardness, nitrate nitrogen and phosphate phosphorous at three sampling locations for two consecutive years on monthly basis. The study of physico-chemical parameters indicated that the quality of Ganga river water has substantially declined. Detoriated water quality of river has potential health risks to drinking water consumers and organisms in Ganga river basin. They concluded that the Ganga River gets seriously polluted due to discharge untreated sewage and industrial effluents and the residues of pesticides and insecticides used in the farms are washed in to it from the point and non point sources. [Singh, D. R. *et al. (*2013)]

2.11 Previous research works on rivers other than Ganga River

A study was made by Kumar, Sujeet *et al.* (2012) to determine the surface water quality status of river Varuna in Varanasi City UP. Water quality assessment of river Varuna was done on the basis of 15 parameters at 32 different sampling sites between Kotwa (upstream of Varanasi City) and Aadikeshav Ghat (Ganga- Varuna Sangam). Appreciable deterioration in water quality of the river could be observed from upstream of Varanasi City to Ganga Varuna Sangam. Alarming depletion of dissolved oxygen level in river water was an indication of disposal of untreated sewage and industrial effluent. To assess the quality of water of river Varuna, each parameter was compared with the standard desirable limit of those parameters in surface water as prescribed by WHO.

The study revealed that Waste generated from tanning generally contains much higher concentration of total dissolved solids(TDS), suspended solids, phenols, chromium, chlorides, ammonia, heavy metals, etc. [Armienta, M. A. *et al*. (2001)]

Tiwari, D. *et al.* (2004) [43] in their study revealed that the untreated discharge of various industries contaminated heavily to river Pandu. Direct dumping of untreated sewage into the river is not only damaging the aquatic life but also human health as river is used for many people as source of drinking water. The multi utility of river water had led to the contamination.

Mohammad Moniruzzaman *et al.* (2009) concluded that Buri Ganga of Bangladesh was one of the most populated rivers of the country. The river bank houses, major industries and factories of Dhaka discharge in to it. A good portion of urban sewage from Dhaka was also drained into the river Buri Ganga. The study conducted on the Buri Ganga water samples aimed to determine the pollution level. Field investigation was started from June 2004 and Sample collection was conducted six times at an interval of two months up to April, 2005. The water quality parameters selected were pH, EC, TDS, DO; Anions (HCO_3^-, Cl^-, SO_4^{2-}, PO_4^{3-}, NO_3^-) and Cations (Na^+, K^+, Ca^{2+}, Mg^{2+}, NH_4^+). Each water sample was examined for these parameters to determine where they exceeded and where they were within the permissible limit. The investigation suggested that in dry season especially, Buri Ganga had the lowest level of Dissolved Oxygen (DO) concentration about 2-3 mg/l. The results indicated that the water of Buri Ganga was not safe for domestic use such as drinking, recreational activities, irrigation and various commercial purposes like fisheries, industrial uses all the year round.

Prasad, N. R. and Patil, J. M. (2011) studied the physico-chemical parameters of Krishna river water in the month of May 2008. Nine samples were collected from different locations. The parameters like pH, EC, TDS, TS, BOD and DO etc. were determined in research lab of DKTE, Ichalkaranji. The results obtained were compared with standards of ICMR and WHO. From the results it was found that the most of the parameters of Krishna river water are within the permissible limit of WHO.

Madhab Borah *et al.* (2011) were taken Surface water samples and collected from pond and river samples in and around of Lumding Town of Assam and analyzed for temperature, pH, conductance, TS, TDS, TSS, turbidity, hardness, total alkalinity, DO, COD, F^-, NO_3^-, HCO_3^-, Cl^-, SO_4^{2-}, Na^+, K^+, Ca^{2+}, Mg^{2+},Fe^{3+}. The results were considered for correlation analysis and it was observed that many of the parameters bear a good positive correlation and some bears a negative correlation.

Maheshwari, *et al.* (2011) studied the quality of surface water of Yamuna River at Agra, UP, India. To analyze for various physico-chemical parameters different points were selected to collect water samples from Yamuna River during winter and summer seasons. It was further investigated the effects of industrial wastes, domestic sewage and agricultural runoff on the river water quality. The study was conducted on most polluted area which was surrounded by many chemical, fertilizers and leather industries i.e. between the Kailash Mandir and Taj Mahal area. The main cause of pollution was due to direct discharge of these industries untreated toxic waste into the Yamuna River.

Various physical and chemical parameters like DO, BOD, COD, pH, total suspended solid, total dissolved solids, alkalinity, turbidity, hardness, chloride contents, sodium, calcium, electrical conductivity were determined for different samples and compared with the standard limits recommended by WHO. The analytical results showed that during winter season, the quality of water was more suitable for domestic purpose.

Kumar, Vinit *et al.* (2011) Studied on the river Yamuna which is the largest tributary of the river Ganga. It was further revealed that certain stretches of River are most polluted due to various urban centers are situated on the banks of Yamuna River and withdraw fresh river water for various activities. The entire urban centers located on the banks disposed off their waste into the river. The objective of the monitoring studies undertaken for water body is to assess variation in water quality with time. Ten sampling stations were selected along the river for sampling purpose from January to June; 2010.Water samples were analyzed in terms of physico-chemical parameters viz. Temperature, conductivity, DO, BOD, COD, alkalinity, total hardness, Cl^- and F^-. The values of these parameters indicated that Yamuna River is moderately polluted under the study area.

In Madhya Pradesh water quality of the river Narmada gets polluted due to the dumping of the city sewage and industrial effluent of the Security paper mill at Hoshangabad drains. Main nallah are the source of urban sewage into the Narmada River. Due to the continuous changing environment and social industrial activity at Hoshangabad has become a matter of concern which is directly or indirectly affecting the water quality of the river. The research was carried out to study the effect on the water quality due to domestic sewage and effluent from Security paper Mill and ecology of river Narmada at Hoshangabad.

Along the bank of Narmada river four sites were chosen for the study. Water samples of the four stations were collected. Three of which was from the main sewage mixing points and one fresh water sample was taken into account for the research. The samples collected were analyzed, as per standard methods. The parameters such as Temperature, pH, were measured in-situ. The statistical evaluations were also made. The result showed increase in Nitrates, Phosphates, BOD, and Total Coli forms, Number of phytoplankton.

Limnological study was carried out by Ali, Imtiyaz *et al.* (2012) for the period of one year from August 2010 to July 2011 to evaluate the various physico-chemical characteristics of Narmada river in Madhya Pradesh. Samples were collected from sampling stations every month and were analyzed as per standard methods. Minimum value of Total solids, BOD and Chloride were recorded in January month and maximum value in June-July months. The results of study indicate that physico- chemical parameters of Narmada River are within WHO limits.

The physico-chemical parameters of water samples collected from Kosi River at Kosi sampling station, Uttarakhand, was studied. Collection dates back to 2004 and 2005 in pre monsoon, monsoon and post monsoon seasons. Statistical studies were carried out by calculating correlation coefficients between different pairs of parameters and t-test was applied for checking their significance. Standard Physico-Chemical values recommended by WHO were used for comparing with values recorded for the physico-chemical parameters of water samples. It was found that there was an appreciable significant positive correlation holding good for chloride with pH, Mg, Na, hardness and total suspended solids and sodium with hardness, electrical conductivity.

On the other hand a significant negative correlation was found between potassium with turbidity, Cl^-, EC and hardness. Barring the turbidity and BOD for which high values were obtained. All the other physicochemical parameters of Kosi water were within the highest desirable limit or maximum permissible limit set by WHO. [Bhandari, Narendra Singh *et al.* (2008)]

The study by Singh, Jaspal *et al.* (2012) had revealed that water quality of river Ram Ganga was not good. Due to high alkalinity the river water was not suitable for agricultural purposes. The value of COD was much higher than BOD, indicated that most of the pollution in Ram Ganga, in the study zone, was caused by industrial discharge. The non-point sources like agricultural run-off, cattle-dropping etc were the main sources of organic pollution.

Agarwal, Animesh *et al.* (2011) carried out a study on different industrial and domestic activities to assess the extent of pollution in River Gagan (India). During summer, winter & rainy season samples were collected from two sites to analyze the alkalinity, BOD and COD for river Gagan. The data collected proved to be a good correlation in establishing a link in between alkalinity & BOD and alkalinity and COD and is subjected to statistical analysis also. To predict the level of pollution in river water regression equations also established between above parameters. As per the present study, it can be used to predict the value of one parameter if value of other is known by establishing regression equation between two parameters. The research could be used as a tool to determine the value of physicochemical parameters and theoretically prove the extent of pollution.

Srivastava, Anukool *et al.* (2011) were aimed to estimate current status of Physico-chemical chararacterstics and level of sewage pollution indicator bacteria and their variation at whole stretch of river Gomti. The sampling covered from upstream to downstream regions of the river representing pre monsoon (January-April), monsoon (May-August), and post monsoon (September-December) in two years i.e.2008 and 2009. Eight water samples were subjected to Physico-chemical analysis like Water temperature, Total Solids, Total Dissolved Solids, Total Suspended Solid, Conductivity, pH, COD, BOD and DO. The bacteriological study of these samples included bacteriological parameters like Total Coli (TC), Faecal Coli (FC) and Faecal Streptocoli (FS) had given the information regarding the suitability of the water for various uses like drinking and other domestic applications. The results are based on Spatial Variation, Seasonal Variation and Temporal Variation. Conclusions revealed that large number of drains in Lucknow city and industrial discharge is mainly responsible for pollution in river Gomti.

Mithani, Imran (2012) had studied and analyzed the physico-chemical characteristics of river Wardha from samples collected at several points of river Wardha. The total environment is a complex entity of which water is the essential component for survival of all the living beings. Life in aquatic environment is largely governed by physico-chemical characteristics and their stability in ecosystem. The precipitation which is the main source of water gets contaminated as soon as it reaches on the earth's surface and during its flow anthropogenic activities in surrounding area further add impurities in it. The water samples of river Wardha were collected monthly for a period of one year from different sampling stations along the stretch of river. During study period, river maintained well alkaline nature of water in study area.

Parameters like dissolved oxygen, conductivity, total hardness, total alkalinity and pH showed variation from upstream to downstream. Dissolved oxygen was found to be maximum during winter might be due to low temperature. However, conductivity, total hardness and total alkalinity were found to maximum during the summer season.

Jena, Vinod *et al.* (2013) collected different water samples of Kharoon River during the period 2010 and 2011 for the assessment of the physico-chemical parameters of samples collected following the standard methods of sampling and testing. The physic-chemical analysis has been carried out for turbidity, pH, EC, total dissolved solid, conductivity, dissolved oxygen, biological oxygen demand, total suspended solid, chloride, total alkalinity, hardness, sodium, potassium, calcium, magnesium and sulfate. The standard permissible values as recommended by WHO was compared with the obtained physico-chemical parameters values of the water samples. Various physico-chemical parameters of river water were taken for the determination of the correlation coefficient. Due to scarcity of the water resource database the observed values was couldn’t validated due to this it was recommended for the frequent monitoring of Physico-chemical parameters of Kharoon water resources was imperative.

Industrial effluent discharge constitute major source of water pollution. Effects of effluent discharge from three paper mill industries on recipient Owerrinta River was determined by subjecting samples to standard physicochemical analysis. All values were within standard excepting the pH value of Effluent-II sample and Total Suspended Solids values of all the effluent samples. There were significant variations between effluents and river samples and within effluents and river samples respectively, for all the parameters.

Variations in the values of different parameters from River samples indicated impact from effluents discharge, while variations in effluents values implied the contributory pattern of the effluents to River quality. Treatment of effluents to insignificant values will reduce the impact on River quality. [Emeka, Ihejirika *et al*. (2011)]

Industrial wastewaters entering a water body represent a heavy source of environmental pollution in Nigerian rivers. It affects both the water quality as well as the microbial and aquatic flora. Industrial effluents are characterized by their abnormal turbidity, conductivity, chemical oxygen demand (COD), total suspended solids (TSS), biological oxygen demand (BOD), and total hardness. Industrial wastes containing high concentration of microbial nutrients would obviously promote an after-growth of significantly high coliform types and other microbial forms. Organic pollution is always evident and the pollution is made worse by land-based sources such as the occasional discharge of raw sewage through storm water outlets and industrial effluents from refineries, oil terminals, and petrochemical plants. Waste effluents rich in decomposable organic matter, is the primary cause of organic pollution. Waste waters from textile, brewery, food and beverages, paper, pulp and palm oil industries, the cases chosen, are believed to give a broad outline of industrial wastes as well as disposal problems. [Kanu, Ijeoma and Achi, O. K. (2013)]

Documentation on water quality based on seasonal distribution pattern of physico-chemical characteristics of the three major rivers flowing in Imphal, Manipur were carried out during July, 2011 to June, 2012. Significant seasonal variations of the different parameters were observed and the study has great value in terms of river ecosystem as well as water quality in different seasons. [Alexander *et al*. (2013)]

Physico-chemical parameters of River Asa in Ilorin metropolis, Kwara state, Nigeria and three surrounding wells were determined and compared for possible interaction and correlation. Water samples were collected accordingly during the raining and harmattan period, physico-chemical analyses were carried out on the samples. Results obtained indicate that apart from the temperature and pH that were related in the harmattan and raining season respectively, variations were observed in other parameters. In comparison, the river sample relatively has higher values than that of the well samples in some parameters such as color, turbidity, total dissolved solid and total suspended solid. On the other hand, the total hardness, alkalinity, chloride as well as nitrate were found to be relatively higher in the surrounding wells while sulphate & phosphate were relatively low. Similarly, heavy metal ions were of higher value in the river, but lower values for the well samples. [Okeola, F. O *et al*. (2010)]

It is very sad to see that many rivers are being polluted by disposal of sewage and untreated industrial wastes due to which destruction of river life, imbalance of eco-system and harmful effects of human life as well. Many studies, analysis and research work has been carried out to analyze physico-chemical properties of Ganga throughout its stretch by various researchers but the pity is that still our holy river Ganga is one of the highly polluted rivers of the world.