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Original Research Article

Control Chart Model for Assessment of Water Quality of a Tropical River-Kshipra Ujjain, India

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Abstract: The present study involves assessment of water quality of Kshipra river by use of control chart, water quality index (WQI), physico-chemical and microbiological analysis. Samples were collected from five sites of the river for a period of one year. The main purpose of the study is to provide a baseline data regarding pollution control, management and improvement of water quality of this river before Mahakumbh 2016. Analysis of various parameters like dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), total coliform (TC), fecal coliform (FC), turbidity, transparency, total alkalinity, total hardness, chloride, calcium was performed.WQI values ranged from 284.0-1112.34 and shows all study site to be under pollution stress. Results of the present investigation showed that water quality of the river is more deteriorated during summer followed by monsoon and winter season. Control chart model is applied for the first time in the analysis of water quality, as it provides a clear pictorial view about the pollution status of the river. The sample mean values in control chart cross lower and upper limits consistently in all seasons and at all study site, indicating very poor water quality. Higher pollution load was observed in Ramghat followed by Managalnath, Triveni, Mahidpur and Kshipra village study sites. According to CPCB water of Kshipra river is found to be of D class and river is observed to be under great pollution stress. Immediate remedial measures are recommended to control pollution and improve water quality of the river which is important for proper management and conservation of this holy river.
Keywords: Kshipra river, water quality index (WQI), physico-chemical, microbiological analysis.

INTRODUCTION

Water pollution in river is acquiring more and more attention in India and across the world along with rapid economic development and population growth. Water pollution can lead to a variety of impacts on communities and ecosystem. Water pollution can be related to a number of factors and processes, with multi source, multi stage and multi-objective character sticks. In a country like India, where rivers are considered to be holy and are associated with religious beliefs of people, one of the chief cause of river pollution is performance of various anthropogenic activities and worship rituals like mass baths, dumping of flower, hair, oil, coins and body ashes of departed souls have flooded the river with varying degree of organic and inorganic pollution. River water is the main ingredient for sustaining life of any country, this water is used for various domestic activities for crop and animal production and can also be shared with public, aquatic and terrestrial ecosystem. For healthy living potable and safe water is essential and is a basic need of all human beings to get adequate supply of safe and fresh drinking water. For, planning effective water pollution control strategies a proper determination of exact pollution state of the river is required.

Previously, many ways of water quality analysis like assessment of physicochemical, biological and microbiological parameters of the river water were used for assessment of water quality but such type of analysis is not sufficient without support of any statistical approach. Now, a days use of various indices, statistical approaches and models have mutated the field of aquatic sciences. Apart from analyzing the general trends of physicochemical and microbiological parameters of the river, the present study aims at using two major approaches for the assessment of water quality of river Kshipra. The first approach for communication of water quality is through Water Quality Index (WQI) which provides a single number that expresses overall water quality at a certain location based on several water quality parameters and turns complex water quality data into information that is understandable and usable by general people. Basically

WQI attempts to provide a mechanism for presenting a cumulative derived, numerical expression defining a certain level of water quality [1]. However, second important approach is control chart model which is an statistical tool and comparatively new approach used for the first time in river water quality analysis. It is a simple pictorial device for detecting unnatural pattern of variation in data resulting from repetitive process, thus providing a criteria for detecting lack of statistical control. Any sample point going outside the control limits is an indication that the process is out of control i.e. presence of some assignable causes of variation which must be traced, identified and eliminated. However, if sample point lie within control limits then process is within statistical control. The present paper provides significant information about water pollution in a tropical, holy river which remains flooded with worship rituals and use of control chart provides quick assessment of the pollution status of the river. Acquiring timely information of water quality status of the river and continuous water monitoring programs are the need of the hour, so that proper action can be taken before this water body is fully destroyed.

MATERIALS AND METHODS

Study Area

River Kshipra originates from a hill of Vindhya range, one mile south of Kshipra village lying 12 km south-east of Indore city (M.P.). It flows approximately between latitude 22º49' and 23º50'N, longitude of 75º45' and 75º35'. River flows across Malwa plateau to join river Chambal which later joins Gangtic system. In the present study, five study sites with high anthropogenic activities were selected on the banks of river Kshipra, they include Kshipra village, Triveni, Ramghat, Mangalnath and Mahidpur.

Field Sampling and Laboratory Analysis

Sampling was carried out monthly from November 2013 to October 2014 for isolation of microorganisms. Bacterial samples were collected aseptically using 500 *ml* sterile bottles and were kept in ice bucket, they were then transported to the base laboratory within 24 hours. For analysis of physicochemical parameters, samples were collected in 2lit. sterile bottles which were kept in ice bucket and transported to the base laboratory within 24 hours. The microbiological parameters like total coliform, fecal coliform were isolated by using methods of APHA, (2005). These samples were diluted to $10^3$and were subjected to membrane filtration technique, after filtration membranes were placed on different media which were then incubated at 37ºC for 24 hours. MaConkey Agar and Briliant Green media were used for obtaining fecal and total coliform count. Sampling and analysis of various physicochemical parameters were done by using standard methods given in APHA [2].

Statistical Analysis

Water Quality Index was calculated according to Brown *et al.*,[3]. Control charts, also known as Schewart control chart are utilized to evaluate seasonal water quality of river Kshipra in selected study sites. The present investigation is the first application of Schewart control chart for analysis of water pollution status during different seasons and at different localities. Control charts are plotted on a rectangular co-ordinate axis- vertical scale (ordinate) representing the statistical measures $\bar{x}$ and R and horizontal scale (abscissa) representing the sample number . Hours, dates or lot numbers may also be represented on the horizontal scale . Sample points , mean or range are indicated on chart by points , which may or may not be joined. For, $\bar{x}$ chart, the central line is drawn as solid horizontal line at $\bar{x}$ and upper control limit (UCL) $\bar{x}$ as well as lower control limit (LCL) $\bar{x}$ are drawn at the computed values as dotted horizontal line. Formula used for drawing control chart are following –

Upper control limit = $E(\bar{x}) + 3.S.E.(\bar{x})$
$$\mu + 3\sigma/\sqrt{n}$$
Lower control limit = $E(\bar{x}) - 3.S.E.(\bar{x})$
$$\mu - 3\sigma/\sqrt{n}$$

Central line = $\mu = E(\bar{x})$
Where, E ($\bar{x}$) or μ is arithmetic mean
S.E. ($\bar{x}$) is standard error of sample mean
And n = is sample size

RESULTS AND DISCUSSION

The present study was conducted in river Kshipra to evaluate the pollution status of the river with respect to physicochemical and microbiological parameters, WQI and control chart. Seasonal physicochemical and bacteriological variations of Kshipra river at five different sites from October 2013-November 2014 are represented in Table (1). For the sake of brevity results of three seasons of all five sites are summarized and mean values are presented. About seventeen physicochemical and microbiological parameters such as air temperature, water temperature, pH, turbidity, transparency, hardness, calcium, chloride, carbonate, bi-carbonate, total alkalinity, dissolved oxygen, biological oxygen demand, chemical oxygen demand, faecal coliform, total coliform and water quality index were estimated. Variations registered in different parameters are summed up as following. Air temperature ranged between 9.0ºC-41.5ºC at all five sites where minimum value of 9.0ºC was observed at Mangalnath during winter and maximum value of 41.5ºC was observed at Kshipra village and Triveni during summer season. Similarly, water temperature ranged between 14.6-32.4ºC where lowest was reported during winter at Ramghat and highest during summer at Mahidpur. Gangwar *et.al* [4] reported water temperature within a range of 20.4-21.7ºC, 33.4-35.9ºC and 30.1-31.9ºC in winter, summer and rainy seasons respectively from river Ramganga U. P. Krishna *et.al* [5] reported water temperature within range of 9.25-21.05°C and 8.01-22.13°C from river Kaveri, Tamil Nadu. Temperature also affects chemical reactions and reaction rates within the water thereby influencing its suitability for use [6].

Transparency of any water body is turbidity dependent, higher the turbidity lower is the transparency. In the present study, the maximum value for transparency was observed at Kshipra village (84.0cm) during winter season and minimum value (33.8cm) was reported at Ramghat during monsoon. Low transparency values were recorded during monsoon due to flood inputs with muddy water. Similar trends were reported by different researchers in various ranges Chaurasia and Rajkiran [7], 21-48 cm in Mandakini river, Singh *et al.* [8] reported transparency range 7.5-48.5 cm in Manipur river system and Sabae and Rabeh [9] reported transparency range of 60-220 cm from Nile river Egypt). Similarly turbidity was reported within range of 18-40 NTU where lowest was reported during winter at Kshipra village and highest at Mangalnath during summer season. Maximum values during summer are due to reduction in water volume and higher concentration of organic matter whereas vice-versa minimum turbidity values were reported during winter season. Similar, trends were reported by different researchers (Kumar and Sharma 2002 at Krishna river, Mishra and Joshi [10] at Ganga river Haridwar, Chouhan and Singh from Ganga river Rishikesh [11]. A study reports higher turbidity values during monsoon season due to runoff and inflow of water [4]. Irenosen *et al.*[12] reported turbidity range within 5.6-5.9 NTU in Owena Dam Nigeria. The turbidity values of Kshipra river shows higher value from permissible limit. pH value is the logarithm of hydrogen ion activity in moles/liter. In water solutions variations in pH values from 7 are mainly due to hydrolyses of salt of strong bases and weak acid or vice-versa. Values of pH ranged within 8.0-.8.9 where minimum was reported during winter season at Triveni and Kshipra village respectively. Highest value of pH was reported during summer at Ramghat. The main reason for high pH in summer is due to high pollution load in river during summer which directly influences pH values. A higher value of pH in summer is also attributed to the fact that in summer an increase in photosynthetic activities in the river is observed and natural water are alkaline due to the presence of large quantity of black ashes of dead bodies and other organic materials which are constantly added in Kshipra river. Bhagat *et al.*[13]has reported pH within the range of 9.2-11.7 in Sutlej river Punjab, Gangwar [4] recorded pH values range between 8.1-8.8 from river Ramganga U.P.

Dissolved oxygen is one of the most important and highly fluctuating factor in water [14]. It reflects the physical and biological process of water and its presence is essential to maintain various forms of biological life in water. The effects of a waste discharge in a water body are largely determined by oxygen balance of the system. The organisms become stressed when DO levels drops to 4-2 mg/lit. The present study reports DO within range of 4-7.4 mg/lit. where highest DO was reported during winter season at Mahidpur and lowest was reported at Ramghat during summer season, which is reflection of continuous discharge of organic waste, nutrient input, industrial discharge, agricultural and urban runoff which results in decreased DO content. Bhagat *et al.* [13] observed DO within range of 3.0-9.3 mg/lit where highest values were observed in winter season at Sutlej river Punjab. Zeb *et al.* [15] reported DO to lie within range of 4.5-8.5 mg/ lit where high values were reported in winter and low in summer season in Siran river Pakistan. Gangwar *et al.* [4] reported DO within range of 5.8-6.3 mg/lit in Ramganga river U.P. Krishna *et al.* [5] registered DO ranged between 5.24-11.47 mg/lit in Kaveri river Tamil Nadu. Solanki *et al.*[14]recorded DO values within range of 4-8 mg/lit in Sabarmati river Gujrat. Chaurasia *et al.* [7] reported DO within range of 5.98-7.88 mg/lit in Mandakni river, Bhutiani *et al.*[16] reported DO values ranged between 9.50-11.0 mg/lit in Ganga river. Singh *et al.* [17] recorded DO values ranged between 0.9-6.9 mg/lit in Gomti river which were found to be associated with regions having high sewage drainage and maximum turbidity. Comparatively, low DO concentration pattern can be seen in the present study in Kshipra river which may be due to disposal of domestic sewage, other oxygen demanding waste and pilgrim activities. Biological oxygen demand values indicate organic enrichment and show decay of plants and animal matter in a water body. It is an important parameter to assess pollution of surface and ground water, where contamination arises due to disposal of domestic and industrial effluents. The BOD recorded from all five sites ranged between 14.4-43.8 mg/lit. Highest BOD value was observed at Ramghat in summer and lowest in winter at Mahidpur. In summer BOD value increases due to increased biological activities at elevated temperature, higher concentration of organic matter, reduced flow and volume of water. Lower BOD values in winter indicate reduction of biological activities of microorganisms at lower temperature. Similar trends were observed by Raghuvanshi *et al.* [18] who reported high BOD (7-12.6 mg/lit) during summer season at Ganga river Allahabad. Sharma *et al.* [19] 11.6-23.7 mg/lit from Noyyal river Perur. Behmanesh and Feizabadi [20] 0.4-3 mg/lit from Babolrood river Bangladesh, Zeb *et al.* [15] 0.92-23.98 mg/lit from Siran river Pakistan, Ochuka *et al.* [21] 3.5-12.8 mg/lit from river Ase Nigeria. In the present study values of BOD were found to be much above permissible limits indicating the presence of decomposable organic matter in the river. Chemical oxygen demand (COD) is the amount of oxygen required by the organic substances in the waste to oxidize them by strong chemical oxidant. In the present study, COD values ranged between 45.8-178.4 mg/lit where minimum value was obtained at Mahidpur during winter season and maximum was obtained at Ramghat during summer season. Higher values of COD were observed during summer season due to reduction in water volume, enrichment of organic substances and nutrients. Comparatively, higher COD was observed at Ramghat due to performance of worship rituals and abundance of anthropogenic activities whereas, low COD was reported at Kshipra village due to comparatively less pollution load. Chaurasia and Rajkiran [7] reported COD within range of 12-48mg/lit in Mandakini river, Semwal and Akolkar [22] reported COD range between 11-18.33 mg/lit in Ganga river. Zeb *et al.* [15] reported COD 20.7-28.2 mg/lit in Siran river Pakistan, Singh *et al.* [17] registered COD range between 37.6-60.8 mg/lit in Gomti river U.P., Kumar *et al*. [23] observed COD between 13.6-14.0 mg/lit in Yamuna river. Krishna *et al.* [5] observed COD range between 16.0-35.0 mg/lit in Kaveri river Tamil Nadu. Irenosen *et al.* [12] registered COD between 13.4-14.4 mg/lit from Owena dam Nigeria. In the present study COD values are comparatively higher than other rivers, which denotes more organic pollution in the river.

Alkalinity of water is a measure of weak acid present and of cations balanced against them. Total alkalinity of water is due to the presence of mineral salt present in it. Likewise measuring alkalinity is important in determining river's ability to neutralize acidic pollution. It is primarily caused by carbonate and Bi-carbonate ions [8]. The present study reports alkalinity to lie within range of 189-381mg/lit where maximum values of alkalinity are reported at Ramghat during summer and lowest values are reported at at Mahidpur during winter season. Alkalinity is an important parameter for assessment of water quality as reported by researchers in different water bodies. Kumar *et al.* [23] reported alkalinity within 123-240 mg/lit from Yamuna river at Hamidpur. Bhor *et al.*[24] observed highest alkalinity (791.8 mg/lit) in the month of June from Godavari river at Nasik. Registered alkalinity values ranging between 28-31 mg/lit from Ganga river. Similarly, Raghuvanshi *et al.* [18] recorded alkalinity ranged between 150.7-189.3 mg/lit where higher values were registered during summer. Values of alkalinity are high during summer this is due to low water level, discharge of untreated waste, and addition of sewage and domestic waste etc. The alkaline nature of water could be attributed to the buffering capacities of inorganic substances. Alkalinity itself is not harmful to humans, if the water supply is less however, 100 mg/lit of alkalinity is desired for domestic use. In Kshipra river total alkalinity value exceeded desirable limit at all study sites throughout the study period. Chloride can be taken as one of the main ingredient of water pollution which enters river water from sewage drains of the city, town along with drainage basin and discharge of domestic sewage. Man and other animals excrete very high quantity of chloride together with nitrogenous compound. In Kshipra river chloride is reported within range of 56.90-208.79 mg/lit where minimum value was observed at Mahidpur during winter and maximum was observed at Ramghat during summer season respectively. Higher values of chloride are observed during summer and onset of rain. During summer, water level is considerably low in comparison to other two seasons, due to evaporation of water which raises the concentration of anion. High chloride concentration in water indicates the presence of organic waste, belonging primarily to animal origin. However, the permissible limits for chloride is<250 mg/lit, and Kshipra river system is found to be near permissible limits for chloride concentration. Ramghat study site shows comparatively higher concentration (208.79 mg/lit) due to sewage accumulation and activities like mass baths, washing of cloths and performance of different worship rituals. Urination by humans and animals in river water also tend to increase chloride content of the water body. Semwal and Akolkar [22] reported chloride ranged between 8.8-20.0mg/lit from sacred river of Uttrakhand. Through, chloride concentration in Kshipra river was high and was reported to be near to the permissible limit.

Calcium is a major constituent of various types of rocks and is present abundantly in natural water. Calcium is leached from rocks and is responsible for contaminating water. Disposal of sewage and industrial waste are important source of calcium. In the present study higher values of calcium were registered with a minimum (63.3 mg/lit) at Mahidpur during winter season and maximum (92.18 mg/lit) at Ramghat during summer season. Irenosen *et al.*[12]reported low calcium level from Owena dam Nigeria .2.52-15.90 mg/lit. Bhor *et al.* [24] reported calcium ranged between 2-14.6 mg/lit from Godavari river Nasik. Singh *et al.*[8] reported calcium concentration range between 6.01-17.63 mg/lit from Manipur river system. Higher concentration was reported during summer and minimum during winter season. However, among Indian rivers Kshipra shows higher value of calcium. This variation is attributed to geographical differences, soil composition of the river bed and degree of weathering of rock terrains through this river. Hardness in water comprises the determination of calcium and magnesium ions as they are the main constituent of earth crust and are responsible for rock formation. This often leads to considerable hardness level in surface water. Hardness values in the present study were registered within range of 142-524 mg/lit where maximum values were observed at Ramghat during summer and minimum were observed at Mahidpur during winter season**.** Ramghat is one of the biggest mass bath centre of Kshipra river, it also accounts for high anthropogenic activities and worship rituals. The accumulation of soap films, hair, dead skin, body oil, dirt and body ashes at Ramghat make it to be the most favorable centre for showing increased values of various pollutants. High values of hardness in summer are mainly due to rising temperature, increasing solubility of calcium, magnesium salts and due to reduced water volume. Similar, trends have been reported by researchers in different water bodies. Zeb *et al.*[15] reported mean hardness values of 56.9 mg/lit in winter and 67.7 mg/lit in summer at Siran river Pakistan, Sharma *et al.* [25] reported high hardness values (850 mg/lit) from Hindon river U.P. in summer and lower in monsoon and winter. Bhor *et al.* [24] reported maximum hardness values (791 mg/lit) in June from Godavari river Nasik. However, according to classification of IEPA with reference to hardness, water of river Kshipra is found to vary from being moderately hard to being extensively hard.

The biological character sticks of water and wastewater are of fundamental importance to human health, in controlling diseases caused by pathogenic microbes of human origin and because of the role they played in decomposition of waste [6]. They are also considered as an evidence of the presence of interstitial pathogenic bacteria in water. FC has shown to be an indicator of recent microbial pollution. FC was reported within range of 92-322x10^3 CFU/100ml where higher was registered at Ramghat study site during summer and lowest during winter at Mahidpur study site. TC was observed between 160-768x10^3CFU/100ml where lowest was reported during winter at Mahidpur and highest during summer at Ramghat study site. Higher counts in summer may be attributed to the fact that during summer suitable environmental conditions prevail for bacterial growth. Indiscriminate defecation along the river banks by both humans and other animals that graze along the river banks are major reasons for increased bacterial count and because of these facts Ramghat shows maximum FC and TC counts respectively. Shrivastava *et al.* [26] reported higher FC count during monsoon season from Gomti river. Shawky and Rabeh [9] observed FC count within range of 21-7500 CFU/100 ml and TC count between 240-1,60,000 CFU/100 ml from Nile river Egypt where highest count was reported during summer. Chaurasia and Rajkiran [7] registered FC count ranged between 842-4834 CFU/100 ml from Mandakini river. Sati *et al.* (2011) reported FC count range between 5-170 CFU/100 ml and TC count within range of 25-250 CFU/100 ml from Alaknanda and Bhagirati rivers. However, in present study river Kshipra shows higher count then other rivers which indicates contamination of the river water by fecal matter and presence of pathogenic organisms. However, CPCB [27] recommended that total coliform should be less than 500 in bathing water. DO of 5mg/lit. or more and BOD 3mg/lit. or less. The water of Khipra river does not fit in the above mentioned criteria and is found to be in D class of water with respect to CPCB classification criteria.

WQI ranged from 284.0-1112.34 throughout the study period where highest value was registered at Ramghat during summer season and lowest at Kshipra village during winter season indicating high pollution load. Water quality index was reported in the order as Ramghat>Mangalnath>Triveni>Mahidpur>Kshipra village. Highest WQI at Ramghat suggested that water quality at Ramghat is in most deteriorated state. According to Brown *et al.*[3]water quality index legend ranged between 0-25 indicates excellent water quality, 26-50 indicates good water quality, 51-75 indicates poor water quality, 76-100 refers to very poor water quality and 100 above indicates that water is unfit for use. Similarly, Behmanesh and Feizabadi [20] reported WQI within range of 48-80 from Babolrood river Iran and indicated water to vary between good to very poor among different sites along river. The values of water quality index in Kshipra river are reported to high in all seasons at all respective study sites which indicates consistent pollution state in the river. The present study indicates positive correlation between temperature, turbidity, total alkalinity, total hardness, BOD, COD, FC and TC whereas DO and transparency showed negative correlation with pH, total hardness, BOD, COD, FC and TC. Similar findings were reported by Bhor *et al.* [24] in Godavari river Maharastra and stated that continuously pollution of water sources by human activities may lead to some health problems to humans.

Control charts are applied to any quality characteristic that is measureable, in order to control that characteristic, exercise control on the measure of location as well as on the measure of dispersion respective of the characteristic. A typical control chart consists of three horizontal lines, a central line (CL) to indicate the desired standard or level of the process, upper control limit (UCL) and lower control limit (LCL) to indicate extreme peaks for a standard process along with sample points which indicates state of the sample are exhibited. In the control chart, UCL and LCL and CL are usually plotted with distinct colors. In the present study, control chart is applied to study the water quality of river Kshipra for the first time. Value of different parameters are plotted as sample points and if these points cross the upper or lower limit then the river ecosystem is known to be out of control. For good water quality sample points should lie between UCL and LCL. For, analyzing water quality of the river in different seasons the number of points crossing the limits and the peak value touched by sample point is observed, with the help of which the extent of pollution in different seasons and at different site is examined. In the control chart for Kshipra village study site during winter season CL is 78.00, UCL is 137.00 and LCL is 15.74 four points cross the UCL and four cross the LCL i.e. eight points are out of limit whereas, peak of sample mean is recorded as 300. During summer season, CL is 94.25, UCL is 168.00 and LCL is 20.50 five points cross the UCL and four cross the LCL i.e. nine points are out of limits and peak of sample mean is noticed as 375. During monsoon season, CL is 93.36, UCL is 166.62 and LCL is 20.09 three points cross UCL whereas, four points cross LCL i.e. seven points are out of limit and the peak of sample mean over here touches 325 (Fig.1). At, Triveni study site, during winter season CL is 106.35, UCL is 198.41 and LCL is 15.74 four points cross UCL and three points cross LCL the higher value of sample mean touches 500. During summer season, CL is 188.94, UCL is 353.06 and LCL is 24.86, five points cross UCL and three cross LCL and peak of sample mean touches 700. During monsoon season, CL is 188.94, UCL is 353.06 and LCL is 24.86 five sample points cross UCL and three cross LCL the peak of sample mean over here touches 500 (Fig.2). At Ramghat study site, during winter season CL is 113.75, UCL is 211.59, LCL is 15.74 four points cross UCL and two cross LCL i.e. overall six points cross limits and peak of sample mean touches 625. During summer season, CL is 222.81, UCL is 426.28 and LCL is 19.25 four point cross UCL and two cross LCL i.e. overall six points cross limits, peak of sample mean touches 1000. During monsoon season, CL is 195.71, UCL is 365.45 and LCL is 25.98 three points cross UCL and two points cross LCL i.e. five points cross limits, whereas peak of sample mean touches 800 (Fig. 3). At, Mangalnath study site, during winter season, CL is 105.77, UCL is 188.87 and LCL is 15.74 four points cross UCL and three points cross LCL i.e. seven points cross limits whereas, peak of sample mean touch 600. During summer season, CL is 220.59, UCL is 421.45 and LCL is 19.73 five points cross UCL and two points cross LCL i.e. total seven points cross limits whereas, peak of sample mean touches 900. During monsoon season, CL is 183.89, UCL is 344.69 and LCL is 21.68 i.e. two points cross UCL and two cross LCL the peak of sample mean touches 800 (Fig. 4). At Mahidpur study site, during winter season CL is 58.34, UCL is 93.31 and LCL is 15.74 two points cross UCL and three cross LCL i.e. total five points cross limits peak of sample mean touches 325. During summer season, CL is 154.32, UCL is 333.36, LCL is 24.72 three points cross UCL and four cross LCL i.e. overall seven points cross limits and peak of sample mean reaches 400. During monsoon season, CL is 99.65, UCL is 175.86 and LCL 23.43 three points cross UCL and four cross LCL i.e. total seven points cross limits whereas, peak of sample mean touches 375 (Fig.5). On, examining both the aspects, i.e. number of sample points crossing limits and the peak touched by sample mean during different seasons it is concluded that during summer water quality is most contaminated, followed by monsoon and least contamination of water quality is reported in winter season. Similarly, if site wise comparison is made it is observed that highest peak of sample mean is touched in control chart of Ramghat study site, followed by Mangalnath, Triveni Mahidpur and least is reported at Kshipra village so, it is evident that most polluted site of Kshipra river with respect of control chart analysis is Ramghat>Mangalnath>Triveni>Mahidpur>Kshipra village. However, application of control chart on water quality analysis of the river reveal that water quality of the river is extremely contaminated i.e. out of control.

As far as spatial variations are concerned maximum value of various parameters like pH, COD, BOD, turbidity, total hardness, total alkalinity, chloride, calcium, WQI and lower values of DO were reported during summer season indicating higher pollution load during summer season which is attributed to reduced water volume, increase in temperature and presence of algal blooms, Echhornia sps. which indicates rich nutrient concentration and organic contamination. During monsoon season river flow is increased, but this leads to sediment re suspension and large amount of biodegradable matter is released from sediment to water causing water quality deterioration. Thus, based on analysis of physico-chemical, microbiological and statistical parameters like WQI and control chart, summer is found to be most polluted season, followed by monsoon and least pollution state was reported during winter season. Similarly, as far as site wise analysis is concerned Ramghat is one of the most polluted site of Kshipra river. Presence of brick making activity is observed between Triveni and Ramghat about 100 brick kilns have damaged the flood plains. These pollutants are found to enter the river which contribute to an increased pollution load at Ramghat. In developing countries, the main source of river pollution is mainly via fecal contamination, discharge of untreated waste and sewage in the water body, lack of proper sanitation facilities and agricultural run off. In developed countries, industrial effluents, agricultural runoff, mixing of pesticides and fertilizes with the river or tap water contributes as a major source of water contamination. In such industrialized countries, the success of applied control strategies is confirmed by small number of water- born outbreak caused by various water born microbes. In a resource constrained country like India, surface water is used for drinking, bathing, recreational and holy activities. However, factors like sewage and waste discharge, industrial effluents, agricultural runoff contribute to increase the level of pollution in Indian rivers, but another factor which is a very important reason for pollution of Indian river system is the occurrence of religious festivals conducted on the banks of major Indian holy rivers like Ganga, Yamuna, Godavari, Kshipra etc. The river water gets flooded with many worship rituals and this water if used without proper treatment can lead to various health hazards. River Kshipra hosts the Mahakumbh mela which is a religious festival organized in every twelve years attracting millions of tourists and devotees from all around the world to take bath in this sacred river, this gives rise to massive mass baths further depleting water quality. Apart from washing with detergents, pilgrims offer milk, curd, ghee, flowers, coconuts, coins, ashes and other religious material in water. This material is brought in polythene bags which are dumped by the devotees in the river. These are non-biodegradable so they disturb the aquatic flora and fauna [28]. River Khipra enjoys status of Goddess in Hindu mythology so dumping of body ashes and statues of Lord Ganesha is an evident act observed at the banks of this river. These activities certify that in holy rivers of India mode and nature of pollution is different from water bodies across the world.

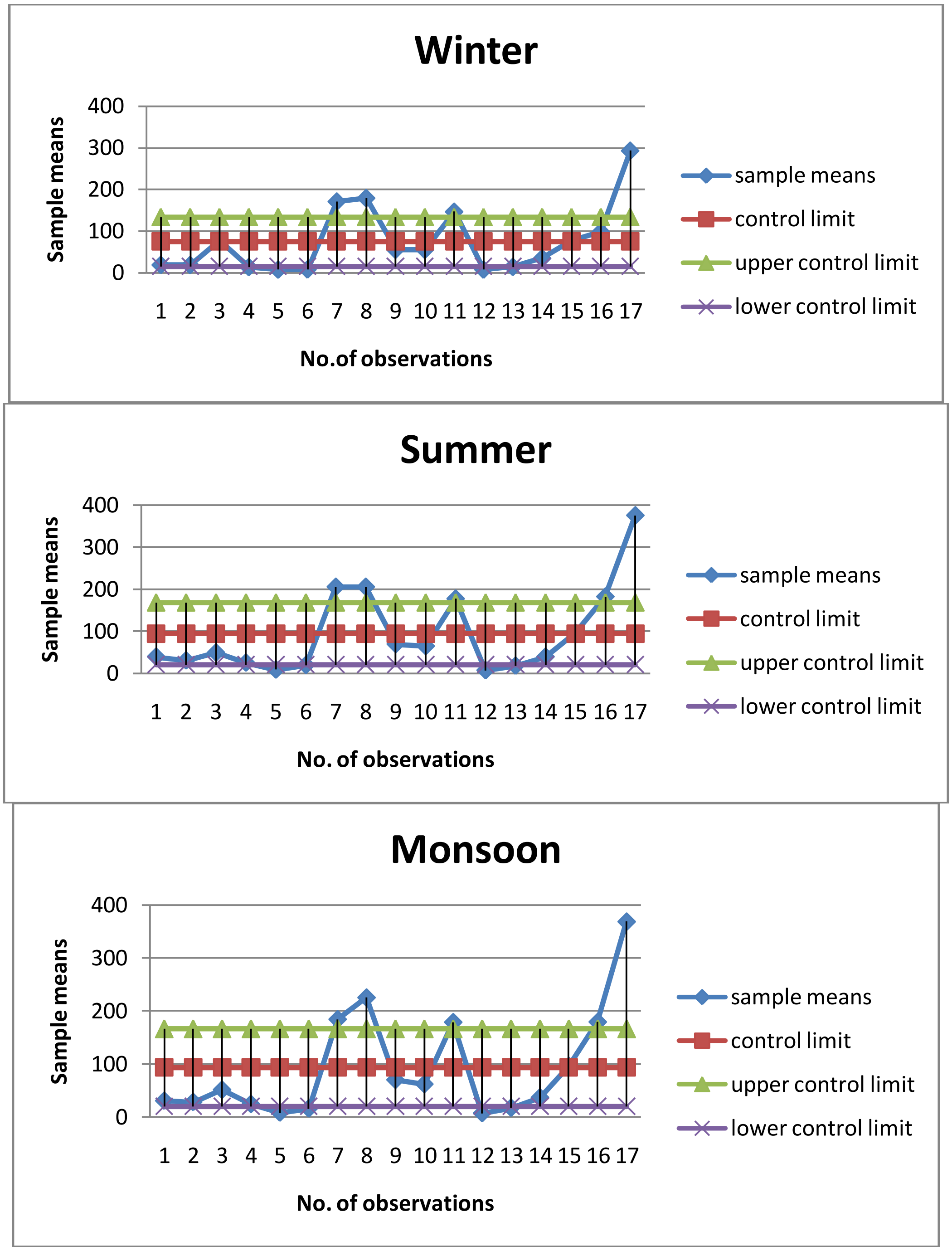


Fig.1 – Control chart for Kshipra village study site

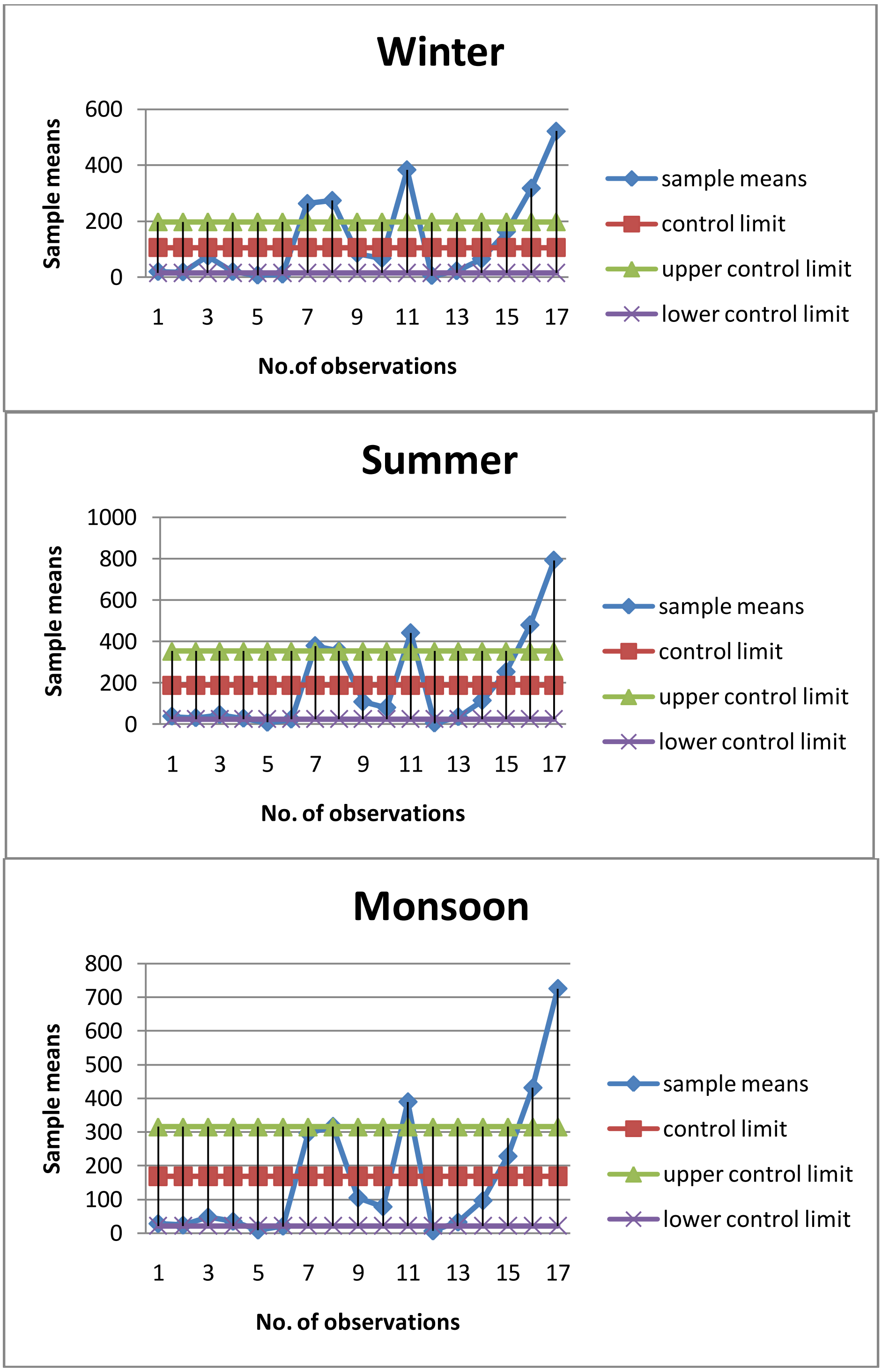


Fig.2 – Control chart model for Triveni study site

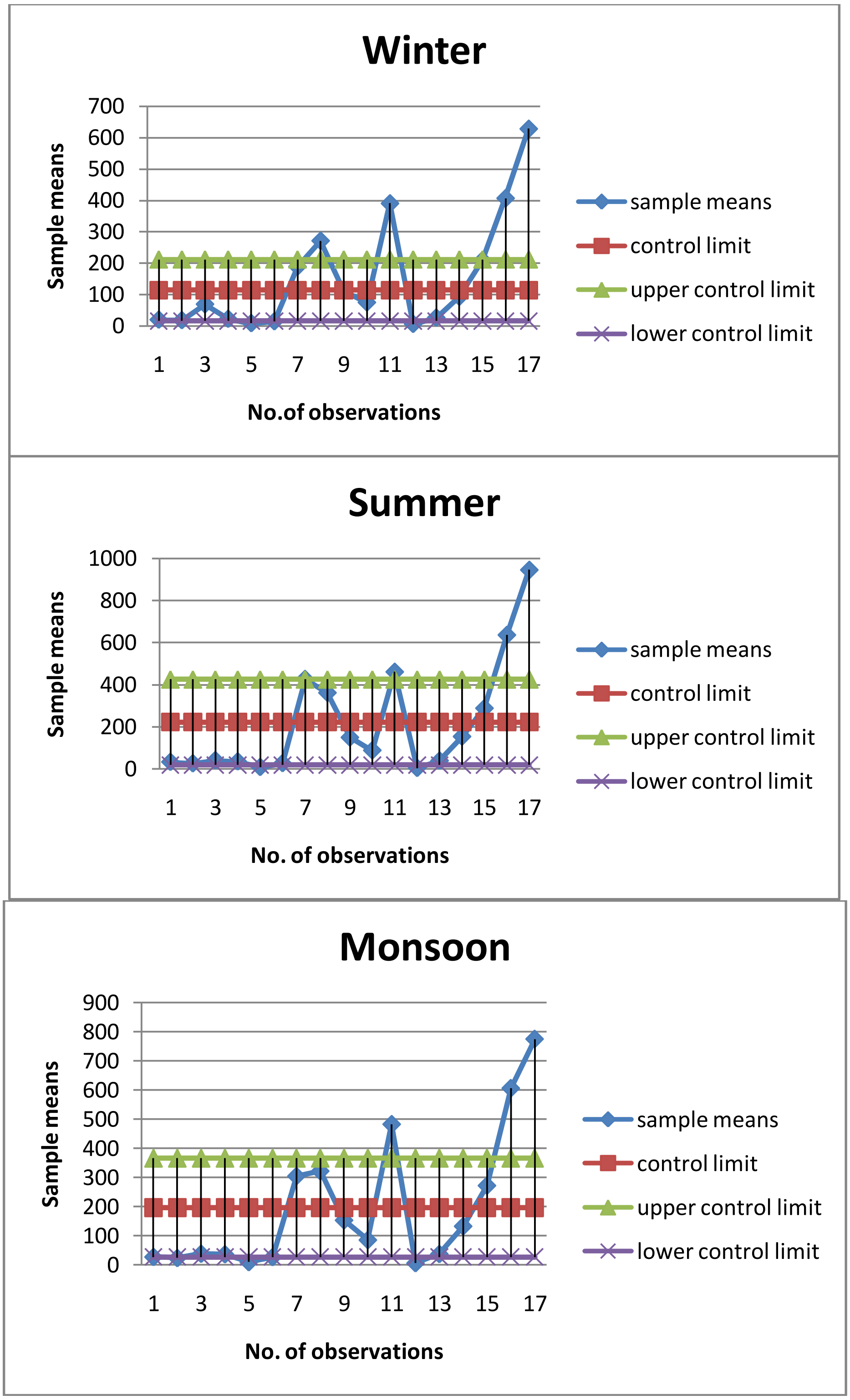


Fig.3 – Control chart for Ramghat study site

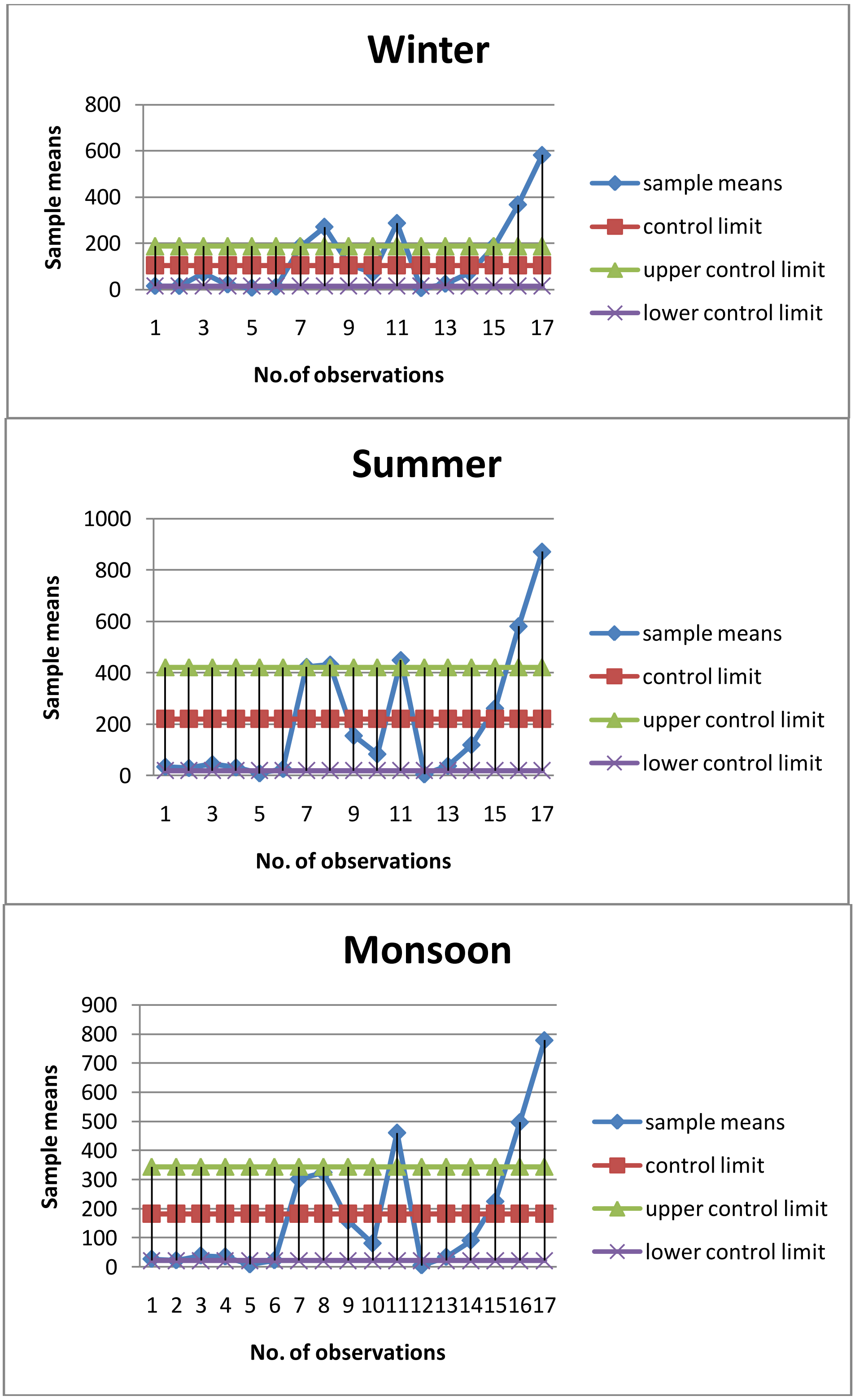
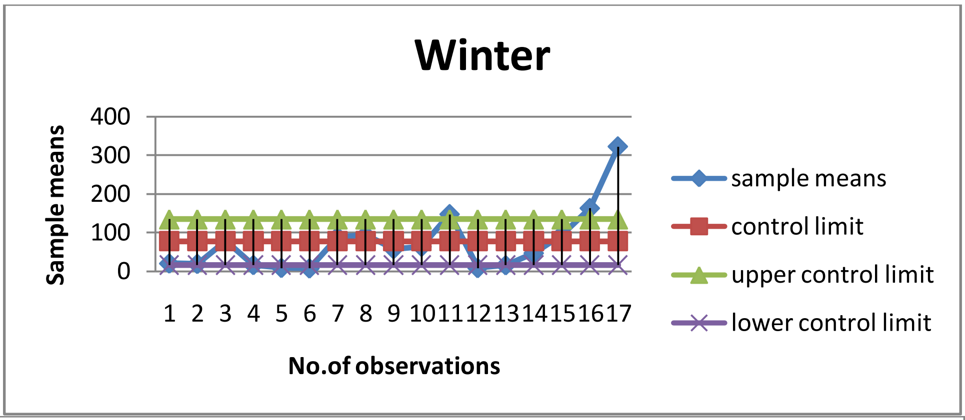
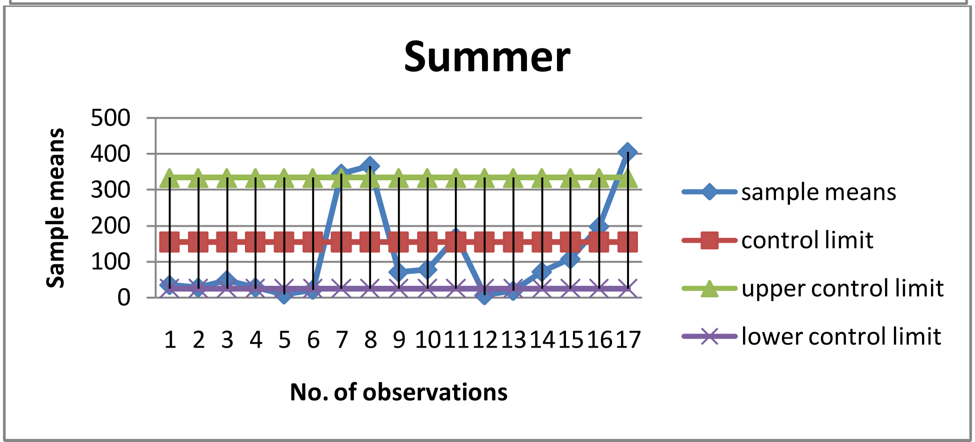


Fig.4 – Control chart for Mangalnath study site





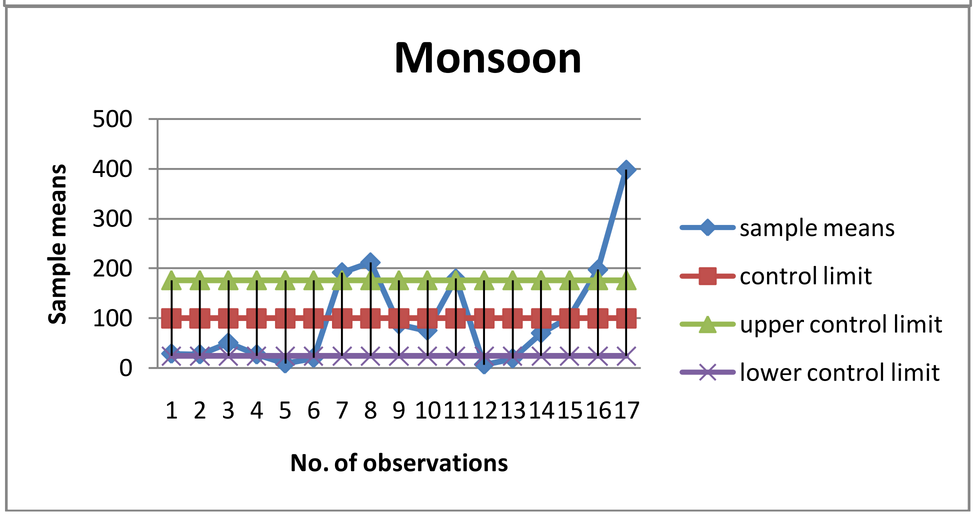


Fig.5 – Control chart for Mahidpur study site

Table 1 - Seasonal variations in Physiochemical and microbiological parameter (mean value) in Kshipra river 2013-2014

S. No.	Parameters	Kshipra village			Triveni			Ramghat			Mangalnath			Mahidpur		
		W	S	M	W	S	M	W	S	M	W	S	M	W	S	M
1.	Atmospheric Temp. (ºC)	19	40.0	31.9	19.4	41.5	28.5	12.2	30.6	27.2	9.0	39.2	27.9	21	37.5	31
2.	Water Temp. (ºC)	18.1	31.2	29.2	17.9	32.4	23.5	14.6	25.8	23.9	10.9	22.8	21.6	17.9	30.2	21.6
3	Transparency (cm)	86	43.0	40	82.4	41.5	36.8	68.2	35.1	33.8	72.4	34.1	40.6	84	42	39
4	Turbidity (NTU)	15	32	26	18	35	39	21	39	36	20	40	37	16	33	25
5	pH	8	8.5	8.3	8	8.8	8.5	8	8.9	8.7	8	8.7	8.5	8.1	8.7	8.4
6	Carbonate (mg/l)	8	24	18	10	28	22	14	33	27	12	25	22	9	26	20
7	Bi-carbonate (mg/l)	176	190	186	234	348	308	242	348	322	240	318	285	180	196	194
8	Total Alkanility (mg/l)	184	214	204	244	376	330	256	381	349	252	343	307	189	222	214
9	Chloride (mg/l)	54.94	74.92	69.93	83.91	118.88	108.89	108.89	208.79	159.84	106.72	175.62	139.86	56.94	75.92	71.92
10	Calcium (mg/l)	55.31	67.33	64.92	66.53	84.96	80.16	72.14	92.18	86.57	70.54	83.36	78.55	63.32	81.76	78.55
11.	Total Hardness (mg/l)	142	190	184	420	432	380	390	524	506	256	504	484	142	190	184
12.	Dissolved Oxygen (mg/l)	7.8	6.6	7.2	6.4	4.8	6	6.4	4	5.6	6.2	5.4	5.8	7.4	5.8	6.2
13.	Biological Oxygen Demand (mg/l)	13.6	19.8	17.6	22.8	40.8	34.2	25.2	43.8	38.4	24.6	36.6	30.4	14.4	20.4	19.2
14.	Chemical Oxygen Demand (mg/l)	33.4	39.8	36.8	64.2	130.8	102.4	90.2	178.4	134.8	74.2	88.2	82.6	45.8	88.6	74.6
15.	Fecal Coliform (X 10^3 CFU/100ml)	74	98	97	158	290	270	202	322	290	182	226	247	92	112	102
16.	Total Coliform (X 10^3 CFU/100ml)	138	196	180	309	600	482	402	768	622	358	538	446	160	212	198
17.	Water Quality Index	284	412.71	372.80	509.65	929.98	796.76	609.15	1112.34	919.42	568.11	996.41	827.93	316.63	442.51	403.62
18.	Control Limit	78	94.25	93.36	106.35	188.94	168.56	113.75	222.81	195.71	105.77	220.59	183.19	58.34	154.32	99.65
19.	Upper Control Limit	137.53	168	166.62	198.41	353.06	315.69	211.59	426.28	365.45	188.87	421.45	344.69	19.31	333.36	175.86
20.	Lower Control Limit	15.7	20.5	20.0	15.7	24.8	21.4	15.74	19.25	25.98	15.74	19.73	21.68	15.74	24.72	23.43

W-Winter, S-Summer, M-Monsoon

CONCLUSION

The maintenance of aquatic life depends on the interactions between physico-chemical, biological and microbiological parameters. Due, to increased pollution levels river water is found to be in highly stressed conditions. The study highlights new and authentic approaches for water quality assessment such as control charts and lays stress on different water quality monitoring and management programs in order to improve the quality of water with minimum sustaining management. Control chart make the assessment of water quality easy because it provides a pictorial view and by just looking at them one can assess the water quality in a glance. The present study shows high values of pollution indicator parameters such as transparency, turbidity, pH, total alkalinity, total hardness, DO, BOD, COD chloride and calcium which confirms the extensive pollution load on the river. Higher values of water quality index in all the study sites indicate very bad state of the river water. Control chart for different sites of Kshipra river shows Ramghat Triveni and Mangalnath to be more polluted in comparison to Kshipra village and Mahidpur similarly, during summer season water is known to be more polluted than other seasons. In order to save this holy river from further deterioration effective pollution control measures must be taken in near future. For this purpose, stringent precautions should be formulated for this river system so that anthropogenic activities in and around the river may not exceed the tolerable limit. The disposal of city sewage, industrial effluents and worship material like coconut, flower and body ashes dumping should be strictly prohibited in and around the river. City of Ujjain awaits Mahakumbh 2016 so certain other steps like maintenance of water volume and minimum flow rates, preventing addition of factory, industrial effluents and domestic waste discharge, providing river water use for irrigation, industrial and religious purpose, construction of research and development wing, creation of river protection force and conduction of regular water monitoring programs should be undertaken, which would help to maintain water quality status of this ancient, religious and holy river and also prepares the river to host massive mass baths.

REFRENCES

1. Miller W.W, Young H.M, Mahannah C.N. & Garret J.R (1986). Identification of water quality differences in Nevada through index application. *Journal of Environmental quality*, 15: 265-272
2. APHA (2005). Standard Methods for the Examination of Water and Wastewater, 21st edn. *(American Public Health Association WWA, Washington, D.C.).*
3. Brown R.M, Mccleila N.J, Deininger R.A &O'connor M.F (1972). A water quality index-crossing the psychological barrier (Jenkis, S.H. ed.) Proc. *Int. Conf. on Water Poll. Res.,Jerusalem*, 6:787-797.
4. Gangwar Ravi Kumar, Khare Puneet Singh, & Singh, A.P (2012). Assessment of physico-chemical properties of water: River Ramganga at Bareilly, U.P. *Journal of Chemical and Pharmaceutical Research* 4(9):4231-4234.
5. Krishna Hosmani Shankar & Jayashankar M (2012). *Journal of research in Science and Technology* 1(6):1-11.
6. Metcalf & Eddy (2003). *Waste Water Engineering Treatment and Reuse.* Fourth edition, New York, USA: MC Graw Hill.
7. Chaurasia Sadhana & Rajkaran (2014). Impact of waste water discharge on water quality of river Mandakini at Chitrakoor, Satna, M.P., India. *Jour. of Env. Scien., Comp. Scien. and Eng and tech.* 3(3):1212-1217.
8. Singh M.R, Gupta Asha & Beeteswari Kh (2010). Physico-chemical properties of water samples from Manipur river system, India. *J. Appl. Sci. Environ. Manage.* 14(4):85- 89.
9. Sabal Shawky Z & Rabesh Saleh A (2007). Evaluation of the microbial quality of river Nile water at Damietta branch, Egypt. 33(1):301-311.
10. Mishra S And Joshi B.D (2003).Assessment of water quality with few selected parameters of river Ganga at Haridwar. Him. *J. Env. Zool.* 17(2);113-122.
11. Chauhan Avinash & Singh Suman (2010). Evaluation of Ganga water for drinking purpose by water quality index at Rishikesh, Uttarakhand, India. *Science publications* 2(9):53-61.
12. Irenosen Oyyakilome Gloria, Festus Ademola & Coolborn Akharaiyi Fred (2012).Water quality assessment of Owena multi-purpose Dam, Ondo state, South-western Nigeria. *Jour. of Env. Protection* 3:14-15.
13. Bhagat S, Chauhan & Sagar S.K (2013). Impact of pollutants on the water quality of river Sutlej in Nangal area of Punjab, India. *Biological forum*, 5(1)113-123.
14. Solanki H.A, Ehitnis R.D And Bhavsar H.A (2012). Physico-chemical and bacterial analysis of Sabarmati river in Ahmadabad. *Life science and Leaflets* 2:70-82.
15. Zeb Bibi Saima, Malik Amir Haider, Waseem Amir And Mahmood Qaisar (2011). Water quality assessment of Siran river, Pakistan. *Int. Journal of physical sciences* 6(34):7789-7798.
16. Bhutani R, Khanna D.R, Kulkarni Dipali Bhaskar & Ruhela Mukesh (2014). Assessment of Ganga river ecosystem at Haridwar, Uttarakhand, India with reference to water quality indices. *Appl water Sci* (6):14-20.
17. Singh Chhatrapal Singh, Jay Shankar Kumar, Vikas Chandra Ram & Kumar Neeraj (2013). Screening out of coliform bacteria from different location of Gomti river, Lucknow. *African journal of microbiological research* 7(29):3762-3771.
18. Raghuwanshi Divya Singh, Harendra Pandey, Rubi Tripathi, Beenu & Shukla D.N (2014). Physicochemical properties and correlation co-efficient of river Ganga at Allahabad. *BEPLS* 3(3):233-240.
19. Sharma V, Bhadula S And Joshi B.D (2010). Impact of mass bathing on water quality of Ganga river during Maha Kumbh. *Nature and Science* 10(6): 1-5.
20. Behmanesh Ali, & Jeizabadi Zaser (2013).Water Quality Index of Bobolrood river in Mezandaran, Iran. *Ijacs* 5(19):2285-2292.
21. Ochuka Ushurhe (2014). A comparative assessment of water quality index (WQ7) and suitability of river Ase for domestic water supply in Urban and rural communities in South Nigeria. *Int. Journ. of Humanities and social science.* 4(1):234-245.
22. Semwal N & Akolkar P(2006). Water quality assessment of sacred Himalayan rivers of Uttaranchal. *Current Science* 91(4):486-496.
23. Kumar Vinit, Arya Sandeep, Dhaka Anshu Minakshi & Chanchal (2011). *I.R.M.J. Multidisciplinary Research Journal* 1(5):14-16.
24. Bhor, Manjusha, Kadewe Prakash, Bhor Abhijit, Bhor Sheetal, Bhosale Manisha & Bholay, A.D (2013). 64-68. *Int. Jour. of Eng. and Science* 2(20):64-68.
25. Sharma M.K, Jain C.K & Singh Omkar (2014). Characterization of point sources and water quality assessment of river Hindon using water quality index. *Journal of Indian water resource society* 34(1):53-63.
26. Shrivastava Anukool, Shrivastava Shivani (2011).Assessment of physico-chemical properties and sewage pollution indicator bacteria in surface water of river Gomti in U.P. *Int. Journ. of Env. Science* 2(1):325-333.
27. Central Pollution Control Board (CPCB), 1995. Classification of inland surface water (IS; 2296-

1982 CPCB Standard). *Water Quality Parwesh* 1(4).

28. Bhasin Shivi, Shukla Arvind N, & Shrivastava Sharad(2015). Observation on *Pseudomonas aeruginosa* in Kshipra river with special reference to anthropogenic activities. *Int. J. Curr. Microbiol. App. Sci.* 4(4):672-684.