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Comparative studies of water and soil quality scenario from selected sites of two main Rivers viz: river Ravi and Sutlej of Punjab, Pakistan

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Abstract

In this study, physico-chemical parameters of water and soil from two main rivers of Punjab viz: River Ravi and Sutlej have been described. This research work has been done to evaluate pH, Temperature, Carbon dioxide, Total alkalinity, Total hardness, Electrical conductivity, soil texture and Cd, Cr, Pb metal toxicity of both rivers and their impact were analyzed comparatively since the soil and water quality have always strong impact on survival of microorganisms and fish fauna found in aquatic ecosystems. Heavy metals such as Cd, Cr, Pb, etc. are of special concern because they can produce water pollution and chronic poisoning in aquatic animals. The results revealed that though the waters of River Sutlej (Head Ganda Singh site) and River Ravi (Head Balloki site) were found polluted to some extents, however, the physico-chemical parameters of water and soil indicated that these are suitable for irrigation and aquatic life.

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Introduction

Water pollution is one of the major threats to public health in Pakistan. Drinking water quality is poorly managed and monitored. Drinking water sources, both surface and ground water are contaminated with coliforms, toxic metals and pesticides throughout the country. Human activities like improper disposal of municipal and industrial effluents and indiscriminate applications of agrochemicals in agriculture are the main factors contributing to the deterioration of water quality (Azizullah *et al.,* 2011). Water quality is determined by various physicochemical and biological factors, as they may directly or indirectly affect its quality and consequently its suitability for the distribution and production of fish and other aquatic animals (Shuvasish and Arvind, 2017). The physicochemical parameters largely influence many lives related processes of aquatic ecosystems (Rehman *et al.,* 2015). The relationship between some physicochemical parameters and plankton composition on fish production in ponds mainly depends on quality and management of pond water characteristics (Adeogun *et al.,* 2005). The river Chenab is one of the largest rivers in Pakistan with an average annual flow of 5.29 billion cubic meters (BCM). In this study, a segment of 292 Km was monitored for a variety of cardinal water quality constituents. Water quality indices (WQI) were calculated for three uses of the river water, i.e. irrigation, drinking and aquatic life, using the WQI 1.0 model developed by the task group of the Canadian Council of Ministers of the Environment (CCME). The results revealed that the lower river reach (185-233Km) was more polluted than the upper 185 Km segment. In this reach overall WQI ranking was poor for drinking and marginal for both irrigation and aquatic life (Bhatti and Latif, 2011).

The optimum fish production is totally dependent on the physical, chemical and biological qualities of water. Water quality management principles in fish culture have been reviewed to make aware the fish culturist and environmentalists about the important water quality factors which are required in optimum values to increase the fish yields to meet the growing demands of increasing population. (Bhatnagar and Devi, 2013). The relationships between physico-chemical parameters, seasons and fish size have been investigated to determine some heavy metals in water, sediment and gills of Sander Lucioperca. Temperature. pH, dissolved oxygen and EC and measured results showed negative and positive correlations between water content and physicochemical parameters. Positive and negative relations were also found between metal levels and fish size (Basyigit and Ozan, 2012). The presence of heavy metals in the aquatic environment is dependent on wide range of chemical, biological and environmental factors (Ajmal and Razi-ud-Din,1988). Cage culture of fish is one of the proven methods of aquaculture. Cage culture is being looked up as an opportunity to utilize existing inland water sources with great production potential to enhance production from inland open waters. Success of the new aquaculture businesses greatly depended upon the suitability of the reservoir's water quality, its water quality variabilities, pollution and seasonal climatic and mixing events occurring in the new aquatic ecosystem (Devi *et al.,* 2017).

The untreated industrial and sewage wastes arising from industries and metropolitan activities make their passage to the River Ravi, Pakistan, where Balloki Head works is one of the major sites of effluent concentration. This study was designed to evaluate the concentration of various toxic elements in fishes of Balloki Head works compared to a nearby fish farm. At the sites under study, there had been observed alarming levels of toxic metals which are needed to be monitored regularly (Nawaz *et al.,* 2010).

Materials and methods

Selected Sampling Sites

The water and soil samples were collected from Head Ganda Singh site, River Sutlej and Head Balloki site, River Ravi.

Research location

The samples were transported to the Research and Training Institute, Fisheries Complex, Lahore for analysis purposes.

Fig. 1. Map for Head Ganda Singh site, River Sutlej.

Fig. 2. Map for Head Balloki site, River Ravi.

Machinery and equipment

The machinery and equipment included Inductively Coupled Plasma-Optical Emission Spectrometer (PerkinElmer Optima 7000 DV) with all its accessories, Analytical balance (Ohaus Pioneer PA224 Brand), Hot plate (PCSIR, Lahore Brand), Conductivity Meter (Jenco 3173 Brand) and pH Meter (Jenway 3505 Brand).

Analysis Protocols

The physico-chemical water quality parameters taken under consideration included Temperature, pH, Electrical conductivity, Total Dissolved solids, Chlorides, Total Alkalinity, Free Carbon dioxide, Total, Calcium and Magnesium Hardness being analyzed following protocols of APHA, 2012. Soil texture analysis was done following protocols of Boyd, 1995. Heavy metal analysis was carried out following protocols of AOAC, section 993.14, 2007.

Statistical Analysis

The statistical analysis on SPSS programme (Version 22) following Steel *et al.,* 1987 was applied including mean with standard deviation to find the significant differences for the parameters included in this study.

Results and discussion

This study has been done to assess various physico-chemical parameters of water i.e. pH, Temperature, Carbon dioxide, Total alkalinity, Total hardness, Calcium, Magnesium, Chloride and Electrical conductivity of two rivers viz: River Ravi (Head Balloki site) and River Sutlej (Head Ganda Singh site). Beside this, some heavy metals like Cadmium, Chromium and Lead were also analyzed and the impact of their presence was checked on aquatic life found at both Rivers. Soil analysis of both rivers was carried out for texture class, pH, Total alkalinity, Electrical conductivity and Total Dissolved solids. The results have been recorded and are shown in Fig 1-7.

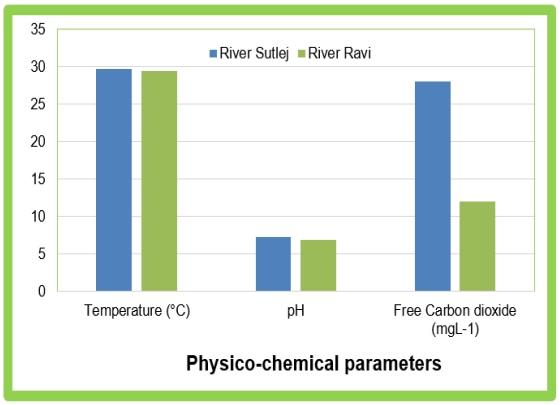

Fig 1. Water Quality Parameter Results (I) from River Sutlej and Ravi.

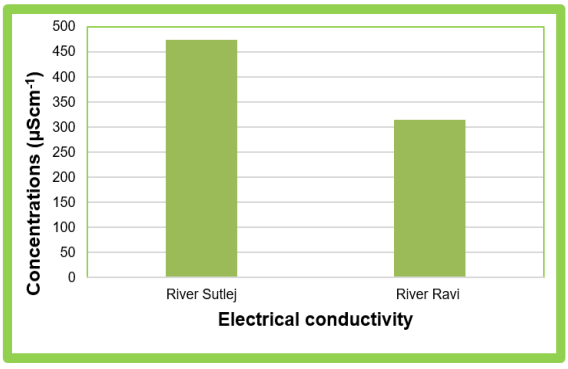

Fig 2. Water Quality Parameter Results (II) from River Sutlej and Ravi.

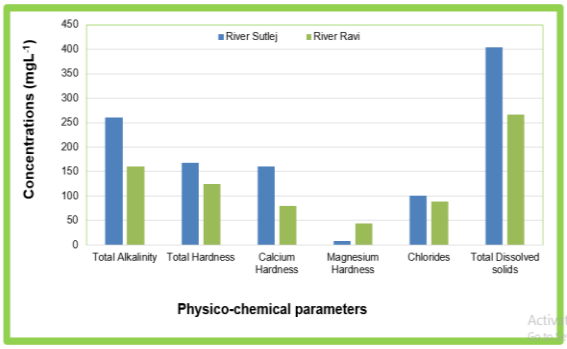

Fig 3. Water Quality Parameter Results (III) from River Sutlej and Ravi.

Water Analysis Results

The temperature of River Sutlej and River Ravi were quite comparable i.e., 29.7 and 29.4°C, respectively (Fig 1). The Fig 1 shows that pH was found nearly neutral i.e., 7.25 and 6.96, respectively for both the sites. The Fig 2 depicted that E.C. was found in the range 475.0 and 314.0µScm^{-1} while TDS (Fig 3) was observed to be 403.75 and 266.00mgL^{-1}, respectively. Chlorides (Fig 3) were found in the range of 100.0 and 88.0mgL^{-1}, respectively. Total Alkalinity (Fig 3) was observed to be 260.0 and 160.0mgL^{-1}, respectively for both rivers. Total hardness (Fig 3) of the water of both rivers was found to be 168.0 and 124.0mgL^{-1}, respectively while calcium and magnesium hardness (Fig 3) were found to be 160.0 & 80.0mgL^{-1} and 8.0 & 44.0mgL^{-1}, both rivers respectively. Free carbon dioxide was found to be 28.0 and 12.0mgL^{-1}, respectively for River Sutlej and River Ravi, respectively. Our research has been supported by the results of Sharma *et al*., 2015 who assessed the water quality of river Sutlej, Punjab (India). Their results indicated that pollution sources clearly deteriorated the water quality of river Sutlej, which in turn affected the ground water in the surrounding areas. Higher values of turbidity have been reported during rainy season in rivers like Vamura. Sunder, 1988 reported that the specific conductivity of inland fresh water for supporting a good fish fauna lies between 150-500 mhos. In his study, the maximum mean annual level of electrical conductivity was observed as 1614±98.68µScm^{-1} at Hudiara nulla. Many systematic studies have been undertaken in Pakistan (Javed and Hayat, 1995, 1996, 1998) in the past to assess the magnitude of pollution in the River Ravi and river Ganga (Chakrabarty *et al.*1959; Joshi and Bisht, 1993). In river Panchnada higher turbidity values during summer have been reported by Narayan and Chauhan, 2000. pH is used for evaluating the acid-base balance present in water and is correlated to electrical conductance and total alkalinity. The higher value of pH recommends that carbon dioxide and carbonate-bicarbonate equilibrium is affected more due to change in physico-chemical condition (Karanth, 1987).

In the present study pH was found nearly neutral which may be due to addition of domestic, municipal sewerages and also agricultural wastes. Dissolved carbon dioxide is the end product of organic carbon degradation in all most all aquatic environments and its variation is often a measure of net ecosystem metabolism (Smith and Hollibaugh, 1997; Hopkinson, 1985). Total Alkalinity is the amount of the balanced cations present across them (Sverdrup *et al,* 1942). In the present study the value of total alkalinity was recorded as 160.0mgL^{-1} in River Ravi and 260.0mgL^{-1} in River Sutlej which is in the permissible limit of 600mgL^{-1} prescribed by BIS, 2012. Total hardness of the water expresses the role of dissolved minerals specially in terms of calcium and magnesium which determines the suitability of water for various purposes such as domestic, industrial, drinking etc. and applied to the presence of bicarbonates, sulphates, chlorides and nitrates of both calcium and magnesium (Taylor and Churchill, 1949). Kane *et al.,* 2015 conducted a research to evaluate the effect of physicochemical parameters and nutrients on fish growth in Narta Lagoon, Albania. Physico-chemical parameters including dissolved oxygen), resulted in normal levels. High concentration of TSS compared to European Directives for ciprinide waters, might have negative effects in photosynthetic processes and the production of dissolved oxygen in water. Based on the results of inorganic nutrients content in water, it was shown that Narta Lagoon is characterized by generally oligotrophic conditions and is suitable for fish growth.

Our results revealed that the river Ravi hardness was comparable to river Sutlej based on water hardness classification showing the suitability for drinking and industrial purposes. Calcium is mainly the micronutrient which is present in an aquatic environment. The hardness of the river water is of chief significance in connection with the discharge of the sewage and industrial pollutants, as shown by variations in the concentration of the hardness of the water. Calcium causes both carbonate and non-carbonate hardness of water (Sharma and Walia, 2015). In a study conducted by Sharma and Walia, 2015, the magnesium hardness also contributes both carbonate and non-carbonate hardness of water. Chloride in river water are mainly due to the presence of sediments, sewage and industrial effluents. In present study, the values of chloride were 88.0mgL^{-1} at Ravi river and 100.0mgL^{-1} at Sutlej river. The conductivity is numerical expression of water's ability to conduct electric current and depends on the concentration of ions in solution. Conductivity measurement is an excellent indicator of Total Dissolved Solids, which is a measure of salinity that affects the taste of potable water. In the present study, the value of conductivity of Ravi river water was 475µScm^{-1} and conductivity of Sutlej river water is 314µScm^{-1}. A slight higher value of conductivity at Ravi river water is due to excess silts. In a similar study, Abubakar, 2013 conducted a research on physicochemical parameters in relation to fish production of Dadin Kowa Dam and found all physicochemical parameters i.e., water temperature range, transparency range, conductivity range, etc. almost within the tolerable limits for supporting aquatic life. Mbalassa *et al.,* 2014 designed a research to determine the physicochemical parameters status along lower Ishasha River and littoral zone of Lake Edward, East Africa. Analysis showed longitudinal differences ($p< 0.05$) along the river. Water was slightly cool, well oxygenated and alkaline at upstream; and contained much more TDS and EC at downstream, indicating the impact of agriculture and deforestation on the river. In the littoral zone the mean values of the parameters remained within the safe limits of water quality standards during the study period in all sites; revealing that physicochemical parameters in these habitats were permissible for most aquatic species. Nadeem *et al.,* 2019 also conducted a detailed study on food preferences in selected Fish Species collected from River Ravi, Punjab, Pakistan and correlated these with the physico-chemical water quality parameters. Onada *et al.,* 2015 investigated the level of interaction among dissolved oxygen, ammonia, pH, and temperature in two culturing facilities (Earthen and Concrete ponds) and concluded that there exists interrelationship among the key water quality parameters examined, and these values varies with time of the day and between different culture facilities. Zeb *et al.,* 2011 conducted a research on spatial variations in water quality of Siran River in KPK, Pakistan. The study showed that the pollution level in Siran river is rising because of discharge of domestic waste water effluent, agricultural activities and solid waste dumping directly into the river. The mean values of the measured parameters were compared with National standard for Drinking Water Quality (NSDWQ) and U.S environmental protection Agency (USEPA) standards. The two downstream stations and were found more contaminated as compared to the other upstream stations.

Metal Analysis Results

The concentrations of selected heavy metals viz: Cadmium, Chromium and Lead showed their comparable values at 0.015 & 0.014, 0.023 & 0.016 and 0.047 & 0.044mgL^{-1} for river Sutlej and river Ravi, respectively as is evident from Fig 4. All these values were found very high as compared to the permissible ranges according to FAO, 1983 and WHO, 1985 guidelines. Muhammad *et al.,* 2011 conducted a research to investigate heavy metal concentrations of drinking water samples in Kohistan region, Pakistan. The study aimed to ascertain potential health risk of heavy metal concentrations to local population. The results revealed that HM in drinking water samples were dictating no health risk. Furthermore, multivariate statistical analysis results revealed that geo-genic and anthropogenic activities were major sources of water contamination in Kohistan region.

Zahra *et al.,* 2014 investigated the heavy metal concentrations in sediments of the Kurang stream using enrichment factor, geo-accumulation index and metal pollution index. Enrichment factor (EF) and geo-accumulation (Igeo) values showed that sediments were loaded with Cd, Zn, Ni and Mn. Comparison with uncontaminated background values showed higher concentrations of Cd, Zn and Ni than respective average shale values. Concentrations of Ni and Zn were above ERL values, however, Ni concentration exceeded the ERM values. Sediment contribution was attributed to anthropogenic and natural processes.

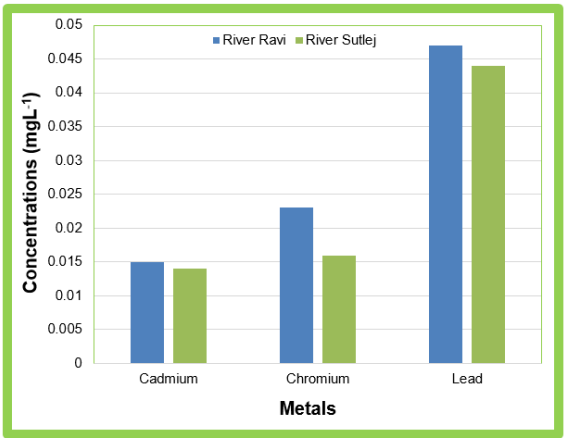

Fig 4. Heavy Metals in water of River Sutlej and Ravi.

Distribution of heavy metals, nutrients and some physico-chemical variables were studied in water suspended and bed sediment samples along River Soan and its tributaries during pre and post monsoon seasons. Nutrient loading in water samples were relative to seasons. Nutrient loading in water samples were relatively high during pre-monsoon season while metal concentrations were found to be high during post-monsoon season. The results suggested that Cd, Zn and Pb threats to aquatic ecosystem should not be ignored (Nazeer *et al.,* 2014). Geochemical speciation of selected metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Sr and Zn) using modified BCR sequential extraction procedure was performed in the sediments collected from Mangla Lake, Pakistan. Among the metals, Cd, Co, Ni, Pb and Sr exhibited relatively higher mobility and bioavailability, while Cu, Fe, Mn and Zn were found mainly in the residual fractions. Cluster analysis(CA) and global contamination factor (GCF) were used to identify the pollution hotspots, which indicated more severe metal contamination at sites near to Mirpur city and other urban/semi-urban areas(S3-S5), especially for Cd, Co, Ni, Pb and Sr (Saleem *et al.,* 2015). The presence of trace heavy metals in the atmosphere, soil and water can cause serious problems to all organisms, and the ubiquitous bioavailability of these heavy metals can result in bioaccumulation in the food chain which especially can be highly dangerous to human health. (Waseem *et al.,* 2014). Metzner, 1977 studied the solubility of copper, lead and zinc at different pH values in waste waters and reported the optimum value of these metals at pH 7. Among the physico-chemical factors, an important factor which influences the availability of heavy metals in the aquatic system is the hydrogen ion concentration (Polprasert, 1982). Mahmood *et al.,* 2000 assessed the physico-chemistry and heavy metals toxicity of water, their results revealed that water was alkaline throughout the stretch under study. On the whole, both zinc and iron toxicities in water were positively and significantly dependent on water temperature while negative but significant on pH of water.

A great deal concern over the last few decades has been directed at the contamination of freshwaters with many different pollutants. The concentrations of heavy metals in the aquatic environment have increased dramatically due to industrial, mining, agricultural, and domestic activities (Abbas *et al.,* 2002). Due to the toxicity of heavy metals and their propensity for accumulating, discharging them into rivers or any other aquatic environment can adversely affect the diversity of aquatic species and damage vital ecosystems (Abbas and Mahmoud, 2004). Aquatic organisms, such as fish and shellfish that live in the polluted water can accumulate toxic metals until the concentrations exceed their concentration in the water to a significant extent. The metals they take up from the polluted water are concentrated at different levels in the various organs of aquatic organisms. For example, in a previous research has shown that cadmium concentrations were much higher in the gills and visceral of aquatic organisms than in their other organs (AbdEl-Hady, 1998).

Cadmium is an extremely toxic heavy metal that is used extensively in mining, metallurgical operations, electroplating industries, in manufacturing vinyl plastics and in making electrical contacts as well as metallic and plastic pipes. High concentrations of metals can accumulate in the tissues of most aquatic organisms because their feeding and metabolic processes concentrate the metals in specific body parts. Some studies of this process on fish have indicated that cadmium may have toxic effects that result in alterations of the physiological processes in the blood and tissue of fish (AbdEl-Kader *et al.,*1993). Thus, it is important to monitor the concentrations of heavy metals in aquatic environments. Currently, there is more awareness of the importance of studying parasites that affect fish. This is important because parasitic species pose a major obstacle to the production of fish, causing about 80% of the diseases that afflict warm water fish (Drastichoa *et al.,* 2004). Eqani *et al.,* 2012 reported the concentrations in surface water of the River Chenab ranged from 27-110µgL^{-1} and 25-1200µgL^{-1} OCPs and 7.7-110µgL^{-1} and 13-99µgL^{-1} for PCBs during summer and winter. Different indicative ratios for organochlorines suggested that current use, long range transport and also past application of these chemicals contribute to the total burden. Statistical analysis highlighted agricultural and industrial activities and municipal waste disposal as main sources of OCPs and PCBs in the riverine ecosystem of the River Chenab.

Soil Analysis Results

The overall results of soil analysis of both rivers are evident from Fig 5-7. The physico-chemical parameters including Total alkalinity, Electrical conductivity and Total Dissolved solids remained at 205.0mgL^{-1}, 697.0µScm^{-1} and 592.45mgL^{-1} for river Sutlej while remained at 470.4mgL^{-1}, 815.0µScm^{-1} and 692.8mgL^{-1} for river Ravi, respectively as is shown by Fig 5. The pH remained to be 8.31 and 8.77 for river Sutlej and Ravi, respectively (Fig 6). The values of silt, clay and sand of Ravi and Sutlej indicate that soil texture class of Sutlej river was sandy while that of river had a silty loam (Fig 7). Values of silt, clay and sand of Ravi and Sutlej indicated that soil texture of river Ravi water was much better and suitable for aquatic organisms as compared to river Sutlej water. In accordance with our research, Yadav *et al.*, 2014 also conducted a research on water and locked soil of different reservoir of West Nimar, M.P. India. The results indicated that some physico-chemical parameters were in permissible limits and some of them were above standard for drinking water so there is need for strict monitoring to ensure quality water supply for human health, irrigation and fisheries. Younas *et al.*, 2017 conducted research on physicochemical parameters of water and soil of three dams in KP, Pakistan. It was concluded that physico chemical parameters of soil and water are in accordance within the giving range given by (WHO, 2015) and also suitable for growing fish productivity.

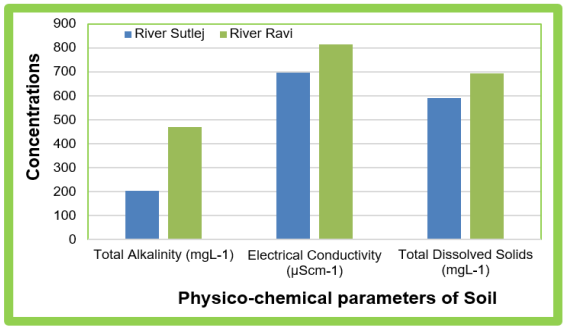

Fig 5. Soil Analysis Results (I) of River Sutlej and Ravi.

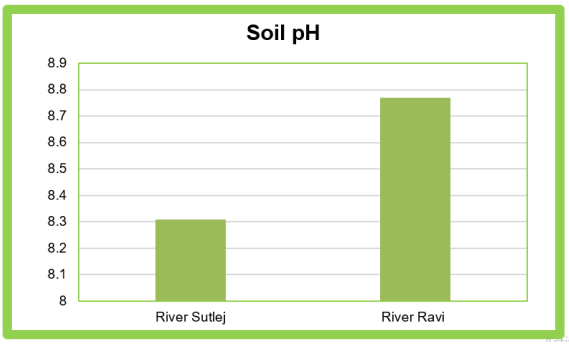

Fig 6. Soil Analysis Results (II) of River Sutlej and Ravi.

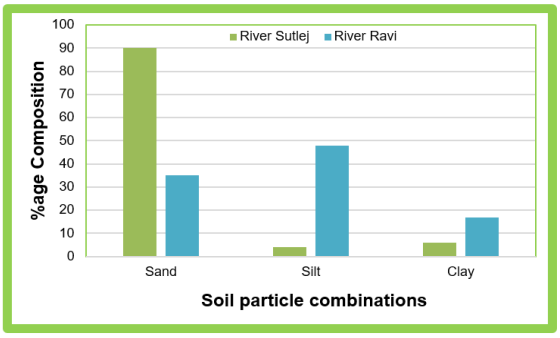

Fig 7. Soil Analysis Results (III) of River Sutlej and Ravi.

Conclusion

The results of this study proved that physico-chemical parameters of water and soil of River Sutlej (Head Ganda Singh) and River Ravi (Head Balloki) though polluted are still suitable for irrigation, domestic and aquatic organisms. It can also be concluded that the presence of heavy metals in aquatic environment were very high than suitable and safe ranges which are again dependent on wide range of chemical, biological and environmental factors. Our research work at Head Balloki and Head Ganda Singh suggested that the risk of pollutants due to addition of domestic municipal sewerages and also agricultural wastes can be reduced by proper sewage treatment and management.

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