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Effects of riverbed extraction on physico-chemical parameters of Tinau River, Nepal

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Abstract

This study was carried out during June 2010 to March 2011 in the Tinau River, Nepal. The level of pollution was determined based on the protocol of US EPA (Habitat Assessment Protocol). Riverbed extraction was occurring in very large scale in this river since 2002. Five sampling stations were selected to carry out the study. Some specific physico-chemical parameters like Electrical Conductivity (EC), Lead (Pb), pH, Iron (Fe), Phosphorous (P), Ammonia ($NH4^{+}$), Nitrate ($NO3^{-}$), Arsenic (As), Total Dissolved Solids (TDS) were analyzed. Three major parameters (Pb, As and TDS) were closely related to the riverbed extraction and exceeded the limit set by WHO for drinking water. Similar relationship was also seen for EC; however its concentrations did not exceed the limit of WHO. The river water was slightly alkaline based on the pH value (ranging from 7.5 to 9).Other parameters did not seem to be related to the riverbed extraction. However, the nitrate and phosphorous concentrations were also high during the present investigation. Lack of similar studies prevented us to compare the result; however these findings provide the baseline data for future work.

Keywords: Riverbed extraction, Tinau River, Physico-chemical parameters, Nepal

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1. Introduction

River is the mirror of society. Many ancient civilizations were flourished on the bank of the River. Butwal is a historical city situated on the bank of the Tinau River where scientist reported the jaw of Ramapithecus. Rivers maintain ecological balance as well as provide source of income if managed properly. Fishes and riverbed materials (sand, cobble, pebble, boulders, etc.) are the sources of income from natural rivers.

Bio-diversity of the aquatic environment and the physico-chemical parameters are inter-related. In an aquatic ecosystem, zoo-planktons play an important role. Fishes eat zooplanktons as their favorite food. These are very sensitive organisms and show changes with any disturbances in their habitat. For example, if there is any disturbance in their habitat, zoo-planktons change their species composition and number. Thus the change in abundance of a species (e.g. fish) is an indication of aquatic habitat disturbance (Sharma et al., 2007).

In the mountainous rivers like Tinau, the extraction activities are growing with the pace of development of engineering infrastructures, urbanization and industrialization. And ultimately, such activities degrade the health of a river. Gravel mining from river channel and floodplain is common throughout the world because it is cheaper than other sources. The economic growth of the world has also invited more construction of infrastructures. And, all these infrastructures need riverbed materials (Kondolf, 1994). On the other hand, riverbed extraction can destroy the vegetative cover of river banks which are important habitats for many aquatic lives. It also protects the river banks and pollution directly entering into the river. The extraction of riverbed materials can change the river morphology in the long run. Tinau is one of the mountainous rivers which contains huge amount of construction material. The River has been providing a huge amount of riverbed materials for the construction and development of infrastructures. The over exploitation of natural resources from this river is being done in an alarming rate.

The river is in a degrading state before it reaches Butwal. The deposition of the river takes place when it enters into the Terai Plain of the Rupandehi District. Particularly, the main deposition part of the river is some 10 km downstream from Butwal (DWIDP, 2011). This area of Tinau River is provided with important construction raw materials such as sand, cobble, pebbles and boulders. Different authors have explained the use and importance of riverbed materials. But there are no such studies with special reference to the impact or change in physico-chemical parameters due to riverbed extraction. Thus this study investigates the effects on water chemistry (with some specific/selected parameters) due to riverbed extraction in the Tinau River. Tinau River originates from the Mahabharat Mountain of the Palpa District. The area of the basin of this river is 1081 sq. km., which extends from 27^0 15' N to 27^0 45' N and 83^0 15' E to 83^0 45' E (Kharel, 2002). Tianu covers geological and topographical zones of Mahabharat, Siwalik and the Terai Plain of Palpa and Rupandehi Districts of Nepal. The river flows into the Terai plain through Siwalik Hills and debouches into the Terai plain in Butwal City before crossing the border of Nepal and India.

The floodplain of the Tinau River is over 5700 hectare. The major tree species found in this region are: *Dalbergia sisso*, *Terminallia tomentosa*, *Acacia catechu*, *Ficus glomerata* and *Bombax ceiba*. The principal ground species are *Clenodendrum visussum*, *Cynodon, dactydon*, *Ipomoea fistulosa*, and *Saccharum spontaneum*. This wetland is an important feeding and breeding ground for several aquatic birds including

Grus antigon (sarus crane), *Egret taalba*, *Ciconia nigra*, *Ibidorhynchas truthensii*, *Sterna albifrons*, and *Nettapus coromandelianus* (JICA, 1999).

2. Study methods

The study was carried out in the Tinau River of Nepal for a year (June 2010 to March 2011). Five sampling stations were selected along the stretch of the River Tinau from Butwal to Bethari (Figure 1). The distance of the selected reach of the River was about 26 Kilometer (from reference zone to recovery zone). The stations were marked with red enamel paint before starting the sampling. The first station was marked with S_1-KU, the second with S_2-KU, the third with S_3- KU, the forth with S_4-KU and the fifth was marked with S_5- KU, respectively.

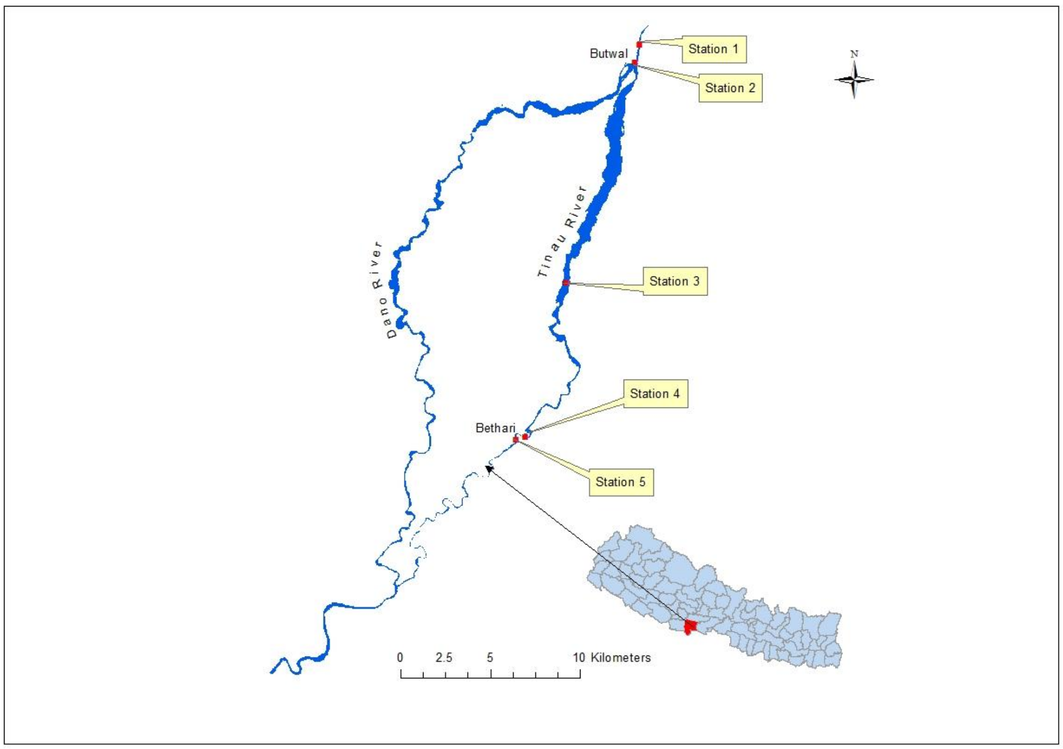

Figure 1. Map showing the location of sampling sites in the study area (Tinau River)

The sampling was performed over four seasons. The first sample was taken in June 30, 2010 representing the dry month and it replicates the characteristics of the dry season. The second sampling was performed in September 30, 2010 representing the rainy month showing the characteristics of rainy season. The third sampling was done in December 30, 2010 which represented the winter month/season. The last sampling was conducted in the month of March 30, 2011 representing the spring month/season. The assumption was made that our sampling times represent all seasons of a year to study the physico-chemical parameters.

The samples were collected in 1 liter plastic bottles. The bottles were rinsed with the river water before collection of water samples. Samples were brought to the laboratory within an hour for the analyses. The sample for the analysis of lead (Pb) was brought to the Aquatic Ecology Centre (AEC) at the Kathmandu University (KU) by preserving in conc. nitric acid (HNO_3). The pH, Iron, Phosphorous, Ammonia, Nitrate, Arsenic and TDS were analyzed in Shankarnagar Water Users' Experiment Laboratory. The Electrical Conductivity was analyzed in Butwal Multiple Campus, Tribhuvan University, Nepal. The statistical analyses were performed by using SPSS-15 software.

3. Results and discussion

Different parameters studied during this investigation are described below in respective subsections.

3.1. Electrical conductivity (EC)

The result shows that the values of EC are greater in station 5 in all seasons. And it has also showed that the values of EC are in similar increasing order from station 1 to station 5 in all seasons (Figure 2).

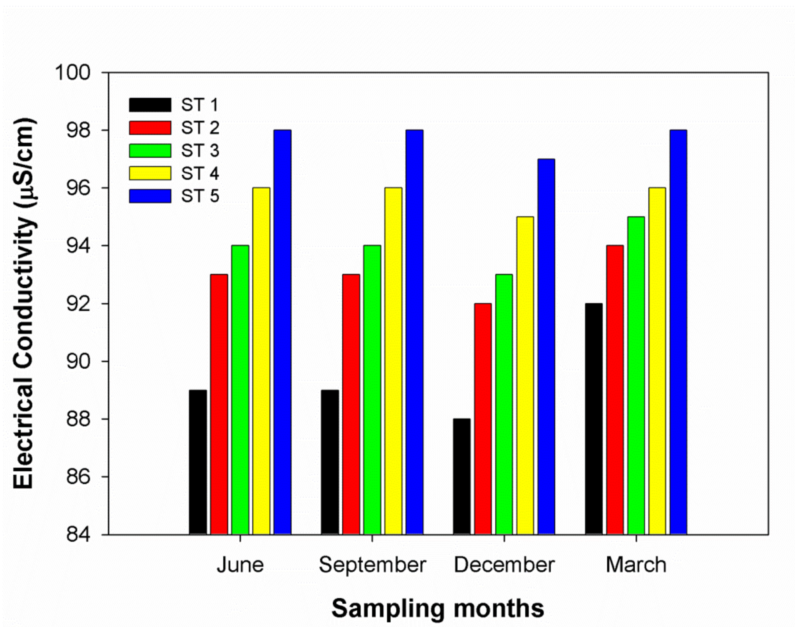

Figure 2. Electrical conductivity (µS/cm) at different stations in the Tinau River in different seasons.

EC ranges from 88 µ S/cm to 98 µ S/cm with an overall mean of 94 µ S/cm. There was a significant difference of EC among study sites (ANOVA; d.f. = 3,16; $p < 0.001$). However, there was no significant difference among different seasons. The EC had a negative correlation with P, As and positive correlation with Pb, pH, Fe, NH4, NO3 and TDS. But the degree of correlation was very poor and statistically not - significant.

EC generally refers to the amount of salt concentration in the water and is measured in an ionic form (Laluraj and Gopinath, 2006). EC in river water depends on various dissolved substances including temperature of the water (Rizwan and Singh, 2009). The greater amount of dissolved solids in river water indicates the greater value of ions in the same water (Bhatt et al., 1999). In our study area, higher EC were recorded in lower stations where mineral salts might have flushed from the upper stations where there is a problem of riverbed extraction. In addition, lower part of our study area receive great amount of local sewage compared to the upper reaches.

The mean EC in the Tinau River was 72.3 μ S/cm during 2006 (Jha, 2006). But the mean EC in this study period was 94 μ S/cm. This is an indication that the pollution in this part of the river has increased compared to the previous condition. One of the major reasons for the increased pollution level might be riverbed extraction.

3.2. Lead (Pb)

The concentration of Lead is maximum in December in station 5 (Figure 3), whereas, it has the lowest concentration in station 1 in March. The value of Pb ranged from 0.008 to 0.075 mg/L with a minimum value of 0.023 mg/L. Pb was negatively correlated with P, pH, Fe, As, and positively correlated with EC, NH_4, NO_3, and TDS. However, the significant negative correlation was observed only with P.

Pb has a great significance to human health due to its toxic effects. The main sources of Pb in the study area were pesticides and petroleum products. In addition, one of the causes of high concentrations of Pb in the present study area might be the increase in riverbed extraction. World Health Organisation prescribes the permissible limit of Pb in drinking water as 0.01 mg/L (WHO, 2006). Based on this recommendation, river water has a risk to human health if used for drinking purpose.

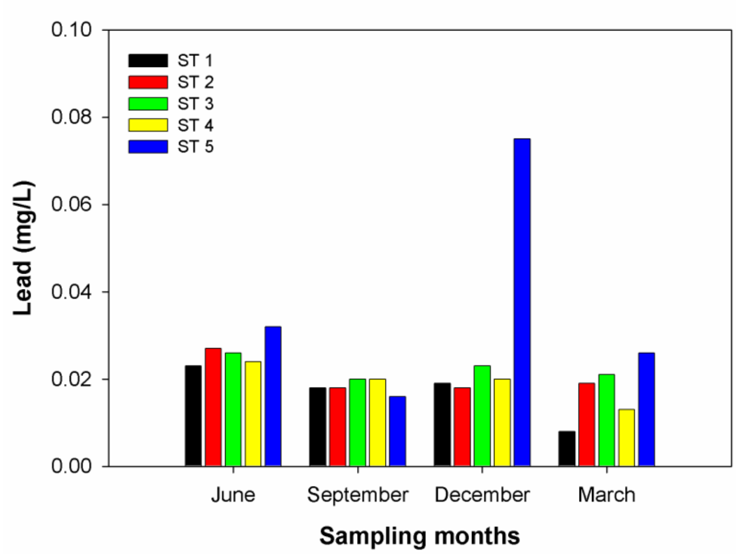

Figure 3. Occurrence of Lead (mg/L) in different seasons at different stations in the Tinau River.

3.3. pH

The river water was alkaline although it varied from station to station. The highest value was recorded in the month of March (Figure 4). The average pH was 7.89 with a range of 7.5 to 9. The seasonal variation of pH was statistically significant (ANOVA; $F = 5.28$; d.f. = 3,16; $p < 0.05$). However, there was no significant difference of pH among different stations. pH was positively correlated with EC, Fe, NH_4, P, NO_3, As and negatively with Pb and TDS.

The average pH in the Tinau River in a study conducted during 1994-95 was 8.29 (Sharma, 1996). A decade later, the mean pH value in the Tinau River was 8.5 (Jha, 2006). There was no decline of pH value during that time. But the mean pH value at present study declined to7.89. Determination of pH is an important part in limnological research because it determines the conditions for chemical reactions (Fakayode, 2005). Although the riverbed extraction began from 1992, the massively extraction occurred during 2002 to 2010. This has led to the increased pollution in the recent period compared to the previous studies (Jha, 2006; Sharma, 1996). Thus the extraction activities may have increased the level of pollution and ultimately it has reduced the pH value of fresh water in Tinau River.

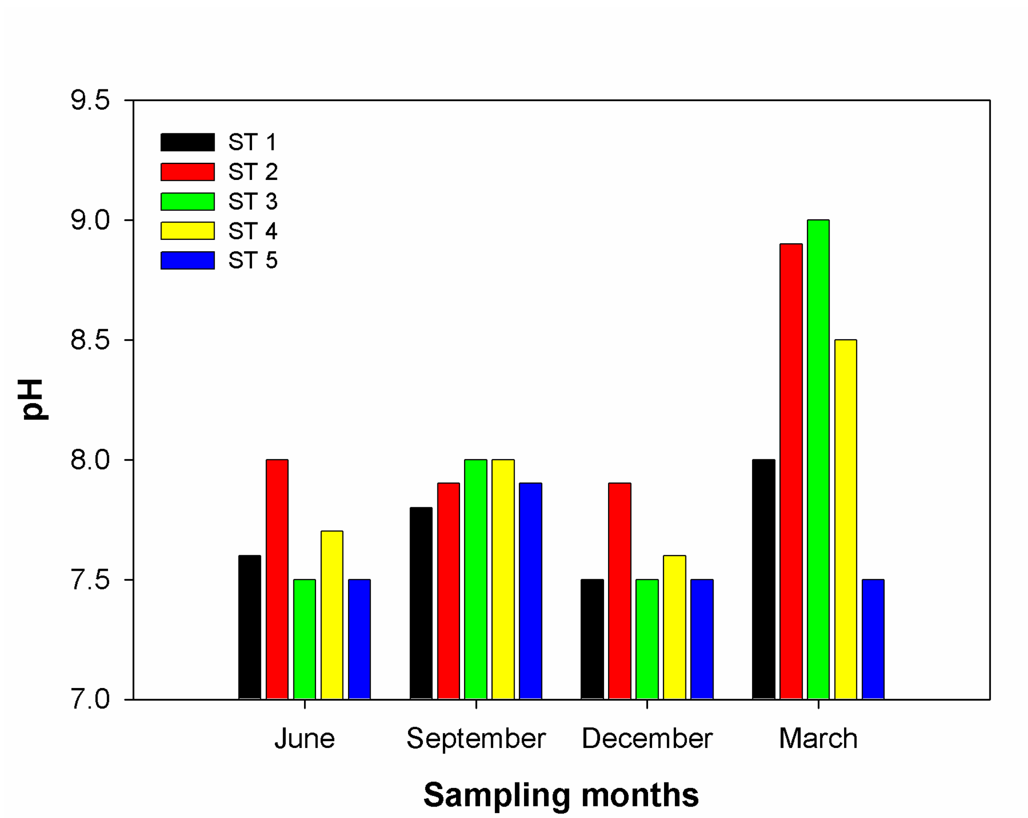

Figure 4. pH values in the Tinau River in different seasons at different stations.

3.4. Iron (Fe)

The value of Fe ranged from 0.01 to 0.6 mg/L with an overall mean of 0.28 mg/L (Figure 5). There was a significant seasonal variation of Fe in the study area (F = 3.45; d.f. = 3.96; p = 0.027) but no difference was observed among study sites. Fe positively correlated with EC, pH, NH_4, NO_3, As, TDS and negatively correlates with Pb and P. But it has significant positive correlation with NH_4 only. The major sources of Iron (Fe) are iron pipe from acid rain, electric board, etc. (WHO, 2006). As Fe is the most abundant metal on the Earth's crust (WHO, 2006), riverbed extraction might have increased the Fe concentrations in river water. The natural level of Fe in freshwater bodies is between 0.5-50 mg/L. The Fe concentration of Tinau River is within the range mentioned by (WHO, 2006), but it was near the lower limit.

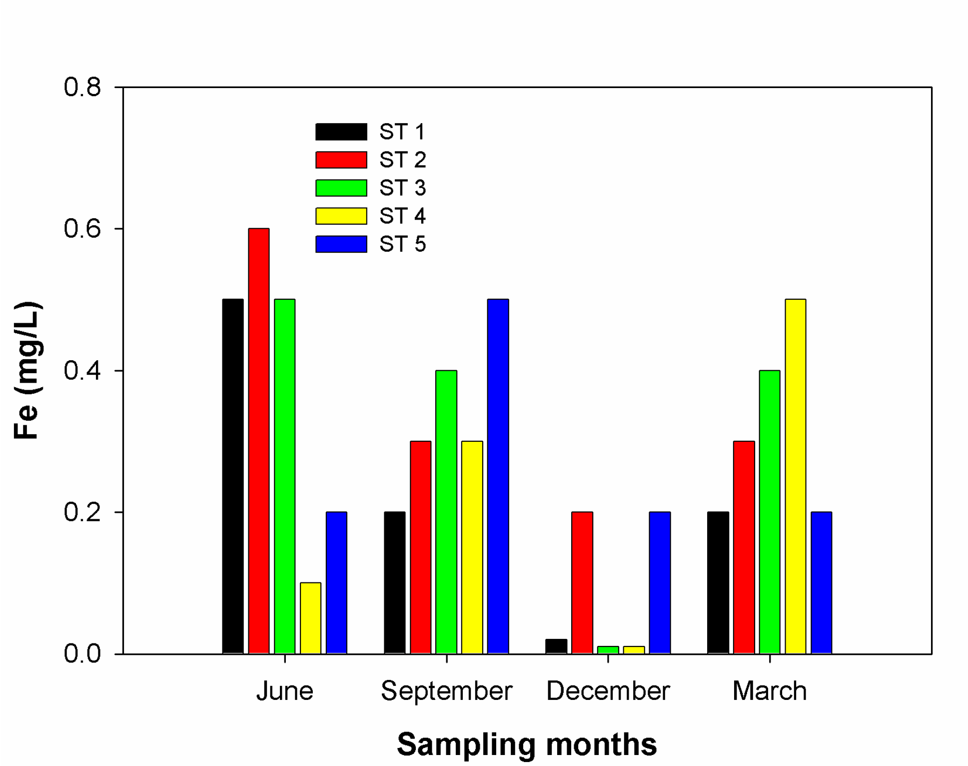

Figure 5. Concentrations of Iron (mg/L) in the Tinau River in different seasons at different stations

3.5. Phosphorous (P)

Phosphorous showed significant seasonal difference (F = 5.28, d.f. = 3,16; p = 0.01) but not site-wise difference. The range of P was from 0.50 to 2.20 mg/L with an overall mean of 1.69 mg/L (Figure 6). There were positive correlations of P with pH and As; and negative correlations with EC, Pb, Fe, NH_4, NO_3, and TDS. The significant negative correlation of P was observed with Pb only. The maximum value of phosphorous is an indication of pollution and it can be the causes of Eutrophication (Stickney, 2005). Mostly, phosphorus is available in the form of phosphate in natural waters. Tinau River receives agricultural runoff, fertilizers (containing phosphate), and waste water containing the detergent from its watersheds that might be the cause for higher levels of phosphorus in river water as indicated by (Singh et al., 2010).

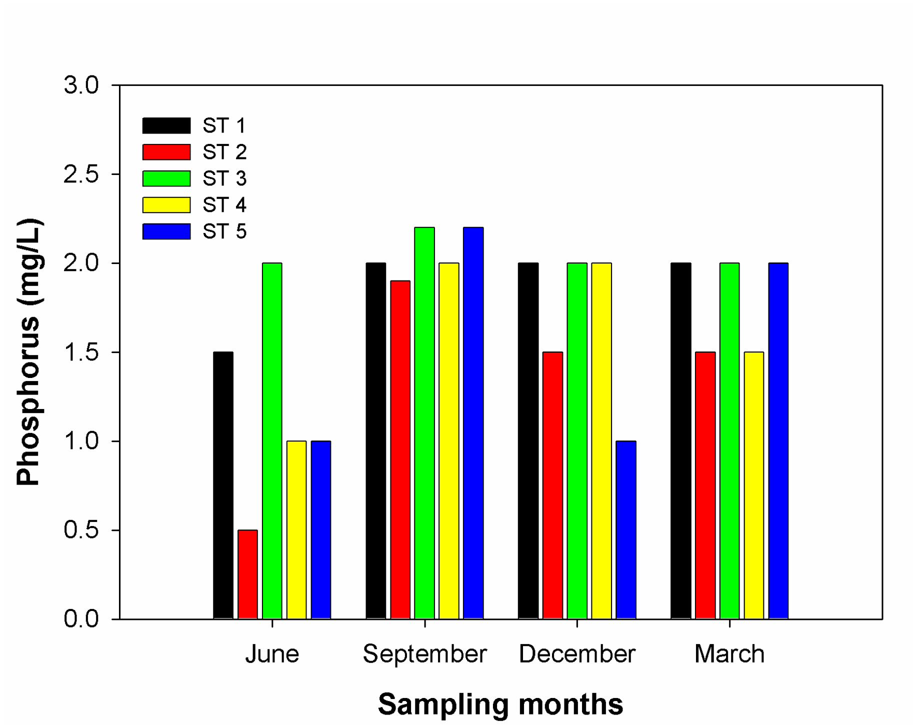

Figure 6. Phosphorus concentrations (mg/L) in the Tinau River in different seasons at different stations.

3.6. Ammonium (NH_4^+)

The value of NH_4^+ranged from 0.50 to 3mg/L with an overall mean of 1.57 mg/L (Figure 7). There was a statistically significant seasonal variation of NH_4^+ (F = 4.54; d.f. = 3,16; p = 0.017). However, site-wise variation was not significant. It was positively correlated with EC, Pb, pH, Fe, NO_3, As and TDS. It showed negative correlation only with P. However, the statistically significant correlations were observed only with Fe and TDS. Usually, the natural freshwater have a value of NH_4^+below 0.2 mg/L (WHO, 2006). The average mean value of NH_4^+ in the study area (1.57mg/L) exceeded the general value of natural freshwater mentioned by (WHO, 2006). Riverbed extraction might be the cause of increment of NH_4^+ in the study area.

3.7. Nitrate (NO_3^-)

The value of NO_3^- ranged from 20 to 49 mg/L with an overall mean of 36.35 mg/L in the present study (Figure 8). It showed significant variations neither seasonally nor among the study sites. Although not significant statistically, it was positively correlated with EC, Pb, pH, Fe, NH_4, As and TDS but negatively correlated with P. The higher level of nitrate is toxic to humans, particularly to infants (Johnes and Burt, 1993). The major sources of nitrate are human/animal waste and runoff from the agricultural lands (WHO, 2006); and the permissible level of NO_3^- in drinking water is 50 mg/L. The levels of nitrate in Tinau River did not exceed the permissible limit set by WHO (2006) so there is no health threat to humans.

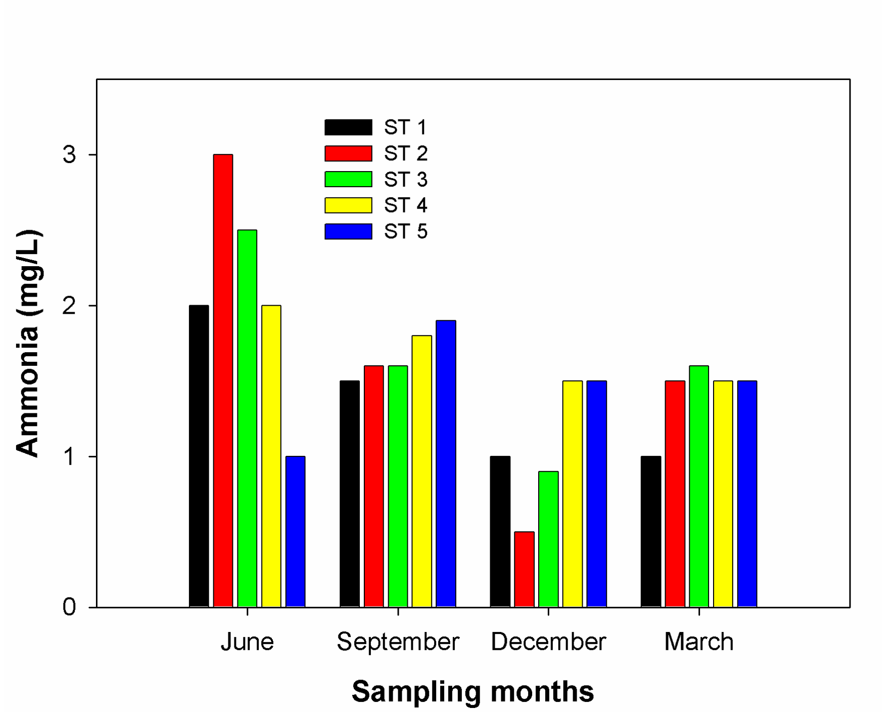

Figure 7. Concentrations of Ammonia (mg/L) in the Tinau River in different seasons at different stations.

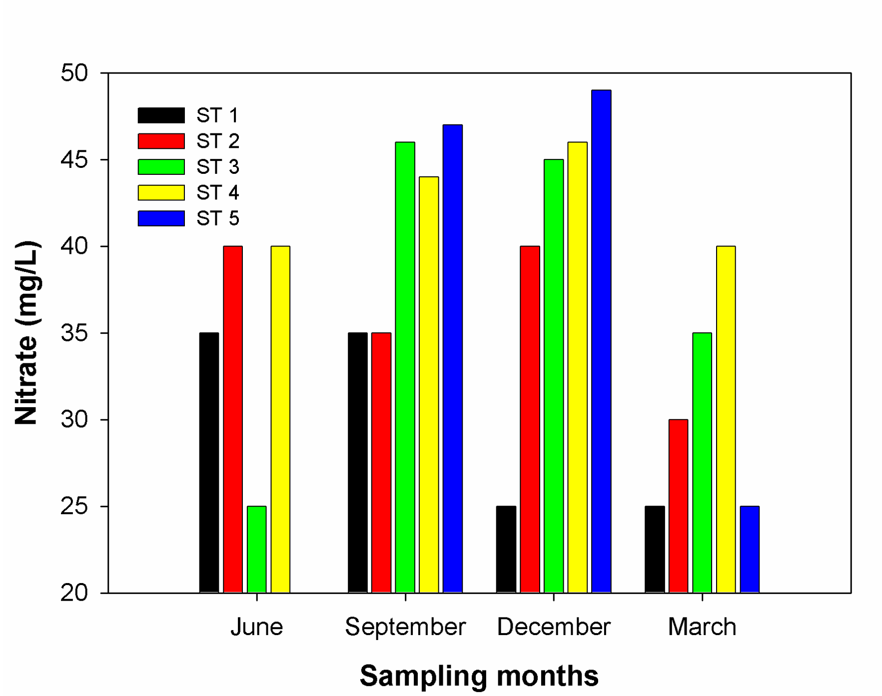

Figure 8. Nitrate concentrations (mg/L) in the Tinau River in different seasons at different stations.

3.8. Arsenic (As)

The value of As ranged from 0 to 0.1 mg/L with an overall mean of 0.02 (Figure 9). It did not show significant variations among both seasons and sites. It was positively correlated with pH, Fe, P, NH_4, and NO_3; and negatively correlated with EC, Pb, and TDS. However, these correlations were not statistically significant.

As is poisonous metal and causes risk to human health. The source of Arsenic (As) is mountains/rocks. In Nepal, Siwalik hill is the source of As. The permissible limit of As is 0.01mg/L in drinking water (WHO, 2006). The maximum use of As can cause skin cancer. As is in deposit form in the riverbed and appears in the surface water when it is extracted. The higher value of As in most of the sampling sites exceeded the WHO recommendation levels for drinking waters. Riverbed extraction might be the major cause for such a high levels of As in river water.

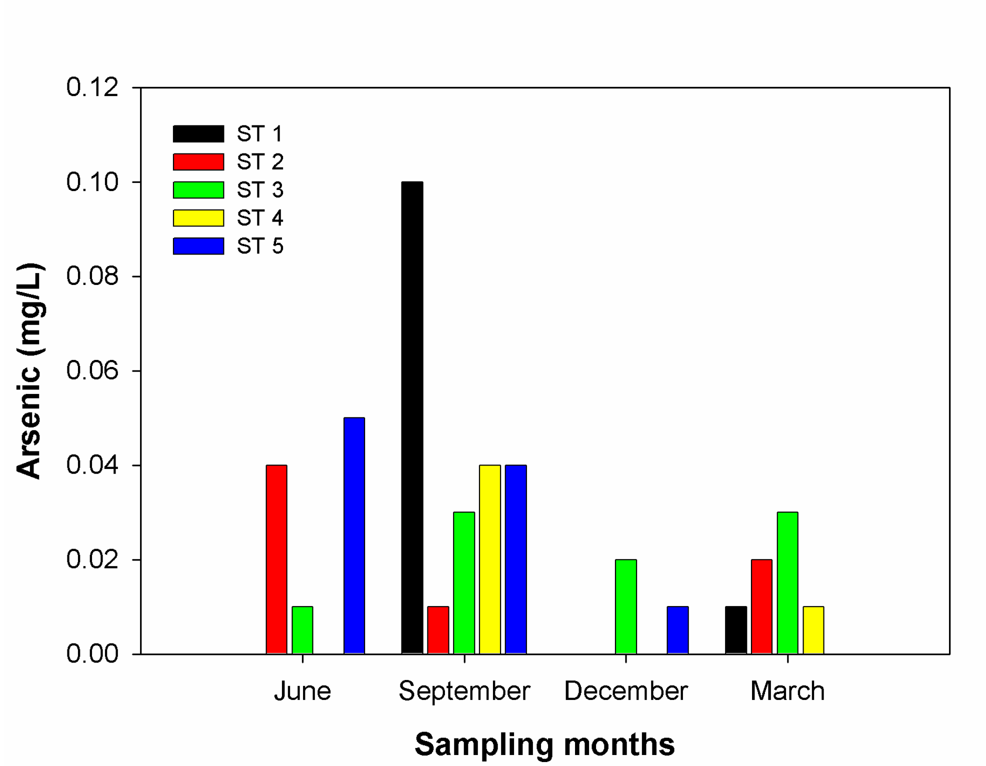

Figure 9. Concentrations of Arsenic (mg/L) in the Tinau River in different seasons at different stations.

3.9. Total dissolved solids (TDS)

The TDS value ranged from 200 to 1200 mg/L with an overall mean of 468.50 mg/L. TDS is significantly different seasonally ($F = 3.42$; d.f. = 3,16; $p = 0.43$) which is highest during June (Figure 10). TDS has a positive correlation with EC, Pb, Fe, NH_4, NO_3 and negative correlation with pH, P and As. However, the significant positive correlation was observed only with NH_4.

Pollution is the main cause of total dissolved solids. There are other causes of TDS in the river water, e.g. sewage discharge, runoff, irrigation water leaching, and landslide. The water becomes unpalatable when the concentration of TDS goes beyond 1000 mg/L (WHO, 2006). In Tinau River, anthropogenic activity like riverbed extraction seems to be one of the vital causes of increased TDS concentrations. When extraction activities increase, ultimately the level of TDS increases. In a study conducted in Manipur River, India higher concentrations of TDS in sand extracted areas were recorded (Singh et al., 2010). The TDS concentrations showed higher values in downstream area which is rich in rocks and soils compared to the upstream area having less exposure to soils and rocks (Nnaji et al., 2011). In Tinau River, the more disturbed sites (stations 2, 3, and 4) showed higher values of TDS compared to the reference and recovery sites in general (Figure 10).

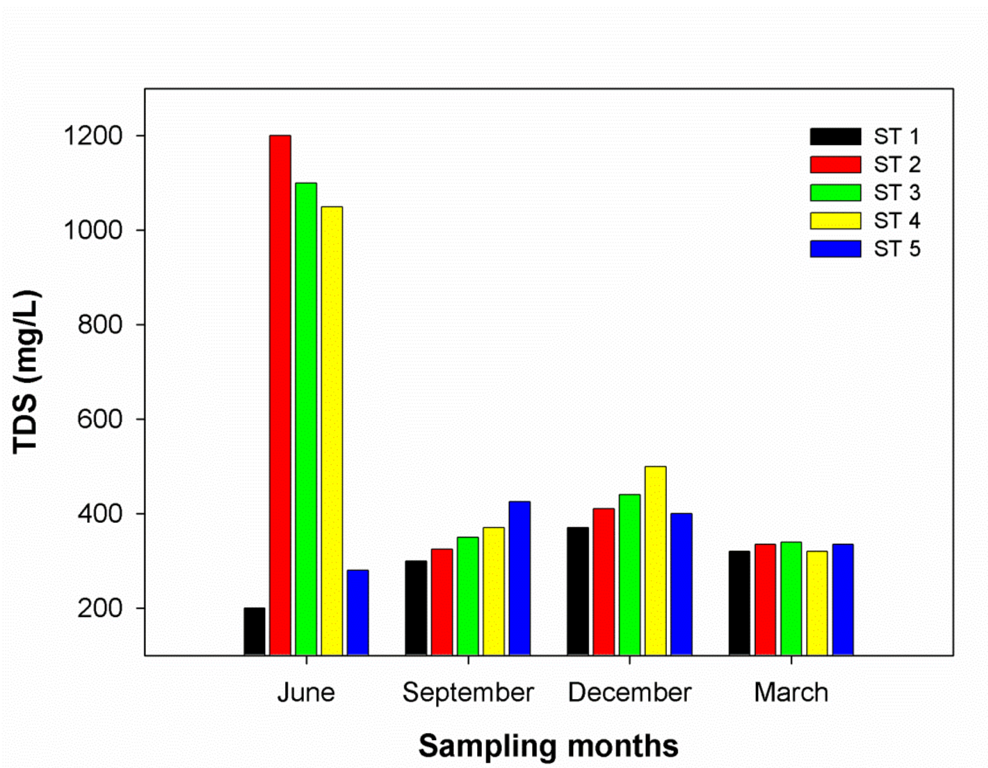

Figure 10: Concentrations of TDS (mg/L) in the Tinau River in different seasons at different stations

4. Conclusion

This study focused on reverbed extraction and some selected river water parameters in the Tinau River. Riverbed extraction and most physico-chemical parameters are interlinked to each other. For example, increased concentrations of Lead, Arsenic and TDS in river water seem to be closely related to riverbed extraction which exceeded the limit set by WHO for drinking waters. Electrical conductivity also showed good relationship with riverbed extraction activity in the river that has increased recently although it did not exceed the level set by WHO. Other parameters studied (pH, Fe, P, NH_4^+, NO_3^-) did not show direct connections with the reverbed extraction activity in the river. The changes in these parameters might have been influenced by some other activities such as industrial wastes discharge and agricultural runoff. Lack of other similar studies in the region made us difficult to compare the results. However, this study helps to build up the knowledge base in this specific research field by providing baseline data that will be vital resource for future research work.

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