Chapter VII

Conclusion & Future scope of work
Conclusions:

The major findings as well as conclusion of the present thesis are as follows:

- In the context of measurement of total As we generally undermined several factors like measurement efficiency, hazerdness and cost. The later one is most pertinent and crucial for developing countries like India, where As is found in rural areas and remote villages. The study clearly indicates that molybdenum blue method is the most suitable one when cost and hazardness have been given priority. Whereas HG-AAS technique is the best suitable practice when sensitivity is the prime factor. A statistical approach has been put forward to support this priority.

- Regular monitoring of multilevel piezometer reveals that the concentration of major aqueous solutes is highest in the shallow part of the aquifer and decreased with depth. The carbonate mineral dissolution is the important process in shallow aquifer, where as iron and manganese reduction is the prevailing process in deeper part of the aquifer. It has also been noted that competitive exchange process ($PO_4^{3-}$ vs $AsO_4^{3-}$) may be another important process to explain As mobilization. Finally, the positive correlation of various oxy anions (U and V) with As, Fe and Mn suggests that the ongoing redox process in the relatively deeper part of the aquifer is possibly microbiolally controlled.

- The high resolution hydro-chemical monitoring study in between high and low As sites reveals that spatial, vertical and temporal variation of As in shallow part of groundwater are controlled interplay of number of geochemical and hydrological processes. These processes are often site specific (operating in local scale). Isotopic signature (δ$^2$H and δ$^{18}$O) further indicate the recharge of evaporative surface water from ponds. The study also supports the reductive dissolution of Fe oxyhydroxide mechanism for the release of As in groundwater under the reducing condition of the aquifer. Another important finding is the degree of
sediment-water interaction and aquifer flushing, which is locally influenced by groundwater abstraction and recharge. These factors are often varying in nature and can explain (at least to some extent) the spatial heterogeneity in As distribution of shallow aquifer of BDP. On the other hand the vertical distribution of dissolved As in ground water (“bell shaped curve”) is likely the result of redox zonation within the aquifer. The phenomenon is often governed by slightly reducing to oxidizing zone (shallower part) vs strongly reducing zone (relatively deeper part). Finally, the high resolution monitoring study of As and other aqueous solutes are very much limited to the upper portion of the aquifer (shallowest part). The nature of variation is often site specific. Different processes such as seasonal cycling of redox conditions, seasonal aggregation and dispersion of colloids, which can potentially scavenge dissolved As, local scale groundwater abstraction for irrigation and monsoonal recharge may explain in the observed seasonal variations in As concentrations.

- The long term monitoring of several piezometers (well-A :12-21 m, B: 22-25 m, D: 30-33 m and E: 34-37 m) reveals that Well-B As concentration is interesting and typical in nature, where As concentration is increasing (post monsoon) and decreasing (pre monsoon) with several peaks. Serious attempts have been made to explain the fluctuation of As concentration in Well-B and in has been found that local recharge (pond) has played as key role regarding the fluctuation of As concentration. Our isotopic signature study reveals that both δ²H and δ¹⁸O isotopic values are clustering on the PEL (Pond Evaporation Line ). This suggests that surface evaporation from pond / wetlands are influencing the local recharge in the study area, at least in local scale.

- Further investigation has been carried out with the help of conservative ion mass balance programme. The results suggest that the infiltration rate of Cl⁻ conc. (possibly from pond) has some influence on well-B As concentration. The correlation studies (between concentration of pond DOC and Well-B DOC, pond Cl and Well-B , pond HCO₃⁻ and Well-B HCO₃⁻) further support the influence of local recharge (pond) on well-B As concentration. Finally, the study also indicates that the fresh organic matter is infiltrating in shallow aquifer, for example (e.g. well-B) there by
As concentration is fluctuating in pre monsoon (decreasing) and in post monsoon (increasing) because local redox conditions are changing along with Fe–oxyhydroxide reduction, depending on availability of fresh organic matter.

- Assessment of various toxic metals (As, Mn, Cr, Mo, Ni, Pb, Ba, Zn, Se, U) in groundwater has been also conducted in the study area. It is important to note that several toxic metals have been identified in groundwater. However, their concentrations are well within WHO guideline values barring As and Mn, when we consider previous (2004) WHO guideline values for Mn. This is important and alarming because health risks can be increased potentially when we consider synergic effect of all the toxic metals. This could be the possible reason that several arsenocosis patients have been identified in the study area, when As safe drinking water has been supplied among the affected population. Finally, we have also measured these toxic metal concentration in human saliva collected from the arsenicosis patient dwelling in an around the study area. This further supports our concern and synergic risks of heavy metals exposure from groundwater.

- The study further advocates the importance of multiple metal measurements in drinking water in an arsenic affected areas and a more careful evaluation on the interactions of these elements with As for the better understanding of arsenic toxicity.
Future scope of work:

The following recommendations are made to assist further better scientific understanding on variation of ground water geochemistry with special reference to As and Fe in different local conditions.

- The four As measurement technique [such as-Iodometric-colorimetric method, SDDC (silver diethyl dithio carbamate method, Molybdenum blue method, HG-AAS (hydride generated atomic absorption spectrophotometric)] have to be performed on bulk sample analysis with moderate life span (at least one year) so that validity, reproducibility and reliability of the suggested molybdenum blue method will be conformed for regional, national even global scale practice.

- At least three replica of long term monitoring study has to be conducted in different parts of BDP (at least one in Bangladesh), so that spatial, vertical and temporal variation of As vs ground water chemistry and redox processes can be matched with our findings. The depth dependent As release mechanism and their geochemical control can provide a clear understanding for the policy makes for sustainable development of shallow aquifer as water resource.

- The influence of pond on shallow aquifer As concentration is an eye opening issue. Because pond is the most common and regular geomorphological signature in rural Bengal. The new tubewell drilling programme as well as ongoing surveillency programme can be regulated with regard to high As concentration wells and their association with pond, so that future drilling programme can be regulated to avoid such influence of pond to the shallow aquifer.

- The presence of toxic metals in groundwater is a serious issue with regard to public health. On the other hand WHO has already with drawn some of toxic metals concentration value for example Mn. More over we have identified several toxic metals in saliva. This clearly suggests that WHO should be more careful regarding withdrawn guideline values and it will be helpful if the Mn guideline value can be reintroduced immediately to safe guard public health.