SUMMARY

The town Deeg famous for world heritage, the Jal Mahal (water palace) is located at $27^0$28' N latitude and $77^0$20' E longitude with an average elevation of 174 m (571 ft.) in district Bharatpur (popular for birds sanctuary: the Keoladeo Ghana National Park), at the eastern gate in the state of Rajasthan (India). The population of town is approximately 60 thousands and has been facing the problem of water quality and quantity for a long time. In our preliminary survey of town Deeg it has been noticed that under ground water is saline and unhygienic. During survey it has also been observed that different kind of diseases such as of diarrhoea, cardiac disorder, gastrointestinal diseases, anaemia, early dental and skeletal fluorosis and early onset of menstruation (in girls) in the residents of this area are prevalent.

The main objective of the present investigations is to assess and identify the quality of well, hand pump, pond and PHED water in town Deeg (Bharatpur) Rajasthan, which have been used for drinking as well as for other domestic purposes for a long time. The study definitely will result in evolution of some cheap technology or alternative method to improve the water quality. Therefore the present investigation has been undertaken to analyse the physico–chemical and biological properties of water, its health effects in human population and the probable remedies to get rid off these problems.

Materials and Methods

The four kinds of water (hand pump, well, PHED supply and pond) have been selected for the study. For the purpose of study the whole town was divided into four areas, that is Nagar road, Jal Mahal, Goverdhan road and Kaman road.

Water samples were collected during pre–monsoon (February, March, April and May), Monsoon (June, July, August and September) and post–monsoon season (October, November, December and January) in every month (October 2017 to Nov.2018). Four samples from each type of water were taken during each season.

All the water samples were assessed for physico–chemical (colour, turbidity, potentia hydrogeni, total dissolved solids, total acidity, total alkalinity, total hardness, calcium hardness, chloride, free CO_2, dissolved oxygen, salinity, sulphate, phosphorus, nitrate, fluoride, chemical oxygen demand, biochemical oxygen demand) and biological (planktons, *E. coli*) characteristics by the method given by Trivedy and Goel (1993), APHA (2005), Manivasakam (2005) and W.I.I. (2006) and compared with the values as guided by ISI (1993). Survey of diseases was performed by the questionnaire.

Results and Interpretations

1. Colour

The value of colour has been noted very higher as compared to limits set for natural water by ISI standards (5–25 Hazen unit) in pond water (all area). The colour of hand pump (Goverdhan and Kaman road) has been noted brownish–yellow that may be due to presence of iron in ground water which on contact with air gets oxidized and imparts brown colour to the water . It is therefore, inferred that the pond and ground water are not suitable for potable purpose with regards to objectionable colour as have been seen in the present study.

2. Turbidity

The higher values of turbidity as compared to permissible limit (5 to 10 NTU) have been noted in pond (all area) and hand pump (Goverdhan, Nagar and Kaman road) in the present investigation. Leaching of organic matter and domestic wastes, mass bathing and washing very dirty cloths and faecal materials may contribute turbidity to pond water. Large heaps of organic matter and decay leaves around the hand pump that may leach into the ground water imparting turbidity to hand pump water (Sastry and Rathee, 1998).

3. Potentia hydrogeni (pH)

The values of pH in all water samples have been recorded within the permissible limit (6.5–8.7) in the present study. However, results indicate that slightly alkaline nature of pond water may probably be due to contamination of water by detergent and soap used for mass bathing and washing cloths.

4. Total Dissolved Solids (TDS)

The values of TDS have been noted higher as compared to permissible limit (500–2000) in all water samples except pond water of Nagar road, Jal Mahal and Kaman road areas. The ground and PHED water contain extremely high TDS in all samples indicating an alarming position.

Vegetable decay, evaporation, chemical weathering of rocks, deposition of hospital waste and mixed waste of domestic and industrial effluents (Sastry and Rathee, 1998; Kumar *et al.* 2006) may be attributed for high TDS. The maximum TDS in pre–monsoon, moderate in post–monsoon and lowest in monsoon season is evident in town Deeg.

5. Total Acidity

There are no specific limits for acidity but it is indirectly controlled by the limits of free CO_2 values. Total acidity exceeds the limit in hand pump (all areas), well (Goverdhan and Kaman road), PHED supply (all areas) and pond water (Goverdhan road, Kaman road and Jal Mahal) in the present study. When the free CO_2 exceeds the prescribed limit, then it is assumed that the total acidity also exceeds the tolerable limits which may be detrimental to health .

6. Total Alkalinity

The levels of total alkalinity have been noted higher than the prescribed limits (200–600 ppm) in well water of Goverdhan road (in all seasons) and Jal Mahal (Pre–monsoon) areas, while remaining samples possess total alkalinity within the tolerable limits in the present study. Seasonal variation in total alkalinity indicates that in pre–monsoon the levels are higher than post–monsoon season. Higher alkalinity may be caused by dissolved minerals in water, carbonates and bicarbonates, pollution load by sewage and its decomposition .

7. Total Hardness (TH)

The samples of hand pump, well and PHED supply water contain very high TH as compared to ISI limits (300 to 600 ppm). The higher values of TH may be attributed to surface runoff, sewage discharge and leaching of calcium, magnesium and other polyvalent cations from soil or rocks naturally (Gupta and Singh 2010 a,b).

8. Calcium Hardness (CaH)

It has been noted that ground water (hand pump and well) and PHED supply water carry very much higher CaH as compared to ISI standards (75–200 ppm) indicating that the water is rich in calcium except pond water of all samples. High CaH might be due to the geological changes in the study area and difference in relative mobility of Ca in the ground water (Garg *et al.* 2008).

9. Chloride (Cl^-)

The high concentrations of chloride as compared to permissible limit (250–1000 ppm) in hand pump and well water of Nagar road, Goverdhan road and Kaman road have been recorded in the present study. The alarming position (4580 ppm) in the well water of Kaman road during post–monsoon season has been revealed. It is evident that during post–monsoon the concentration of chloride is greater than monsoon and pre–monsoon in the town Deeg. The high chloride content in ground water of town Deeg might be due to leaching of chloride rich effluents of domestic (septic tank and pit latrines) and municipal untreated (land fills) sewage.

10. Free CO_2

Free CO_2 exceeds the limit (30–50 ppm) for ground water in hand pump (all areas) and well (Goverdhan and Kaman road) in the present study. The higher levels of free CO_2 in PHED supply (all area) and pond water (Goverdhan road, Kaman road and Jal Mahal) as compared to limits for surface water (less than 10 ppm) have been observed. The minimum value of free CO_2 in the present study has been recorded during pre–monsoon and monsoon season and maximum during post–monsoon season. The higher levels of CO_2 may be due to the presence of decomposable organic matter in the bottom and high dissolved salt contents (Shaji *et al.* 2009).

11. Dissolved Oxygen (D.O.)

Lower levels of D.O. as compared to permissible limits (3.00 to 7.00 ppm) have been noted in pre–monsoon (hand pump and pond water of all area, PHED supply water of Goverdhan road and Kaman road, well water of Jal Mahal and Kaman road), monsoon (pond water of all areas, hand pump water of Goverdhan road, Jal Mahal and Kaman road, well water of Jal Mahal and Kaman road, PHED supply of Goverdhan road and Kaman road) and post–monsoon (pond water of Kaman road) season. The decreased amount of D.O. in ground water might be due to very high salinity, BOD & COD as is evident in the present study . Extremely low D.O. in the pond water may be attributed to the inflow of domestic sewage and waste water and deposition of organic matter and decay vegetation into the pond.

12. Salinity

The high concentration of salinity as compared to desirable limits (0–1500 ppm) in hand pump, well and PHED supply water (Goverdhan, Kaman and Nagar road) has been noted in the present study. Ground water (hand pump and well) has been observed much more saline than pond and PHED supply water. Higher values of salinity in the present study may be due to continuous addition of animal and human excreta and house hold waste along with salts from the surrounding area containing large amount of chlorides. (Mohan *et al.* 2007). High value of salinity has been recorded during the pre–monsoon season followed by post–monsoon season, could be attributed to the low amount of rainfall and higher rate of evaporation .

13. Sulphate (SO_4)

The concentration of sulphate (SO^{-}_4) in the present study has been found well below the desirable limits (200–400 ppm) as given by ISI in all water samples that may probably be due to the lack of sulphite ores and shales in the soil and rocks (Prakash and Somashekar, 2006).

14. Phosphorus (P)

The concentration of phosphorus in the pond water of all areas and well (Jal Mahal) water in all seasons has been recorded high as compared to desirable limit (not more than 0.1 mg/L), which might be due to phosphate rich agricultural runoff, untreated domestic sewage, toothpaste, detergents and pharmaceuticals and the leakage of septic tanks into the pond water . Mass bathing of human and animals by soap, washing of cloths and deposition of excreta of human and animals into these ponds may again be reasoned for increased phosphorus. High level of phosphsorus is an indication of eutrophication.

15. Nitrate (NO_3)

All the samples of ground water (hand pump and well) exhibit nitrate content very much higher as compared to ISI standards (45 ppm) in all seasons. However, an alarming position with regards to nitrate value (376.97 ppm) has been noted in the hand pump water of Kaman road as compared to other samples during monsoon season. Seasonal variation in the levels of nitrate is evident i.e. minimum in post–monsoon some what higher in pre–monsoon and highest in monsoon season. The high levels of nitrate in the ground water in the present study may be reasoned to the deposition of organic matter of human and animal waste, industrial effluents, leaking of septic tanks, and manure from livestock and seepage of sewage through drainage system around the water resources . Maximum concentration of nitrate has been recorded during monsoon season which may be due to high leaching of waste disposed from fertilizers, domestic and municipal sewage, washing of stagnant effluents and agricultural discharges along with rain runoffs . Further, in the nearby areas of town Deeg there are croplands, where a very rich crop of mustard every year forms the major part of livelihood of the people of that area. Since, mustard is a leguminous plant (fix nitrogen into nitrate), the possibility of high nitrate due to this leguminoceae crop can not be ruled out (Batheja *et al.* 2009). The ground water of town Deeg contain very high amount of nitrate which renders the water unsuitable for drinking purpose.

16. Fluoride (F^-)

The concentration of fluoride exceeds the permissible limits (1.00 to 1.50 ppm) in well (all samples) and hand pump (Nagar and Kaman road) water in the present study. The high content of fluoride in the well water may be due to surface runoff of rain water to the low lying areas. Several processes namely dissolution of fluoride bearing minerals, ion exchange (Saxena and Ahmad, 2001) and evaporative concentration may locally account for high fluoride concentration in ground water. The variation in the fluoride concentration in different areas in the present investigation may be influenced by local geological setting and hydrological conditions. Further, the weathering caused by alternative wet and dry conditions of semiarid climate as evident in town Deeg may be responsible for the leaching of fluoride from minerals in the soils and rocks (Rao *et al.* 1993, Saxena and Ahmad, 2001). Again, phosphatic fertilizers used in agricultural activities may also results in high concentration of fluoride in the soil. Ground water of town Deeg because of having high level of fluorides is not fit for drinking purpose.

17. C**hemical Oxygen Demand (COD)**The values of COD exceed the permissible limit (0.5 to 200 ppm) in hand pump and pond (all areas) and well (Nagar road and Jal Mahal) water samples under investigation. The pond water shows more organic pollution than ground water which might be due to high levels of biologically resistant organic substances in pond water. Anthropogenic activities like bathing and washing of cloths in pond water, deposition of domestic and municipal sewage in and around pond, hand pump and well and a great number of landfills in nearby localities in town Deeg may contribute to the high concentration of COD in the present study.

18. Biochemical Oxygen Demand (BOD)

The level of BOD exceeds the permissible limit (0–30 ppm) in all water samples and in all season except PHED supply (all area) and well (Govardhan and Kaman road) water. The highest values of BOD in pond water may be due to the inflow of domestic sewage, deposition of large heaps at the bank of the

ponds and anthropogenic activities. The high value of BOD in hand pump and well water might be due to leaching of untreated organic matter into the ground water. Increase in the BOD may also be due to nutrient loading in the water body which promote toxic algal bloom (phytoplanktons as has been noted in the ponds of town Deeg) leading to destabilization of the aquatic ecosystem (Morrison *et al.* 2001).

19. Phytoplanktons

A total of eleven (11) phytoplankton genera have been recorded in the ponds of Deeg of which one belongs to bacillariophyceae, six to chlorophyceae, three to cyanophyceae and one to euglenophyceae, that make up the bulk of the algal flora of this aquatic environment. The major genera of phytoplanktons in terms of frequency and abundance are *Navicula* (bacillariophyceae); *Ulothrix*, *Spirogyra*, *Cosmarium*, *Chlamydomonas*, *Chlorella*, *Volvox* (Chlorophyceae); *Nostoc*, *Scytonema*, *Oscillatoria* (cyanophyceae), *Euglena* (euglenophyceae). Seasonal variations in phytoplankton diversity is not very pronounced although the highest number of genera are recorded in monsoon and post–monsoon (nine each) followed by that in pre– monsoon (six).

A positive relationship of total phytoplankton density with calcium, phosphorus and total hardness could be reasoned to the fact that calcium is an important part of plant issue and increases the availability of other ions and thus might have increased the growth of phytoplankton in post–monsoon season.

20. Zooplanktons

Zooplanktons (total eight genera) in pond water of town Deeg consist mainly of three major classes i.e. cladocera represented by two genera (*Daphnia* and *Moina*), rotifera by four genera (*Asplanchna*, *Brachionus*, *Keratella* and *Filinia*) and copepoda by two genera (*Cyclops* and *Diaptomus*). The dominant group observed is rotifera while copepoda is the class present in lowest count. The density observed is highest in the pre–monsoon and lowest in post–monsoon. The fluctuation in density is mainly due to decrease in quantity and quality of water, increase in temperature, availability of food and chemical nature of water . Rotifer dominates among zooplankton population in pond of Kaman and Goverdhan road in town Deeg.

21. Microbiological Study

The number of *E. coli* exceeds the permissible limits (less than 10.00 per 100 ml) in well and pond water in the present study. Highest number of the pathogen has been revealed during monsoon followed by pre and post–monsoon season. The pond water shows greater number of *E. coli* than the well water in the present investigation. Very high contamination by *E. coli* of well and pond water in Goverdhan road followed by Kaman road, Nagar road and Jal Mahal have been observed. Very high contamination of water resources (well and pond) due to animal and human waste and unhygienic conditions around the wells and pond (Paliwal and Sati, 2007) may be responsible for the high counts of *E. coli* in the water of town Deeg (Bharatpur).

22. Survey of Diseases

A total eight water born diseases have been noted in percentage during the survey (with the help of the questionnaire) of the town Deeg. The diseases observed are diarrhoea (9.09–19.64%) may be due to unhygienic conditions, gastrointestinal (10.00–16.96%) to high *E. coli*, cardiac problems (12.50–15.00%) to high TDS, anaemia (3.57–6.66%) to high nitrate, skeletal problems (7.14–9.16%) due to high fluoride.

Recommendations:

1. Surface or rainwater should be used instead of ground water in the affected areas after proper treatment.
2. Food rich in calcium and phosphorous are recommended as the rate of accumulation of fluoride in human body decreases when these are consumed in the intestine (Singh *et al.* 2010).
3. Recharging the underground aquifer through the rain water harvesting at appropriate locations can reduce the fluoride content significantly through dilution (Alagumuthu and Rajan, 2008).
4. Do not attempt to remove the nitrate by boiling the water. This will only concentrate the nitrate making levels even higher (Gupta and Singh, 2010a,b).
5. Yellow mustard is effective for the removal of nitrate (Batheja *et al.* 2009).
6. Treatment technologies available in the market for efficient reduction of nitrate in drinking water e.g. electro–dialysis, reverse osmosis, ion exchange must be used.
7. Biological and chemical remediation and mineral treatment (Batheja *et al.* 2009) must be employed.

8. Water should be monitored by the rolling boil then cooling and alum or bleaching treatment before use to minimize the concentration of TDS (Garg *et al.* 2008).

Public should be made aware about the water quality importance and hygienic conditions before use.

SIGNIFICANT FINDINGS

On the basis of the observations of the present study the following significant findings have been revealed:

1. Very high TDS in well and hand pump have been observed.
2. Higher turbidity in all ponds indicates the presence of disease causing organisms.
3. The hand pump, well and PHED supply water contains very high TH (very hard drinking water) that may cause cardiovascular problems (Srinivas *et al.* 2000).
4. Extremely low levels of D.O. along with high COD and BOD have been noted.
5. Concentration of salinity has been noted very high as compared to permissible limit that may be toxic to plant's growth.
6. Phosphorus concentration in the pond water is very high, which indicates eutrophication.
7. All the samples of ground water (hand pump and well) exhibit very much high nitrate content. However, an alarming position with regards to nitrate value (376.97 ppm) in hand pump water of Kaman road has been noted. This may pose serious health problems like methemoglobinemia in babies, anaemia in infants and pregnant women and formation of carcinogenic nitrosamines, if used for drinking purpose.
8. The concentration of fluoride exceeds the desirable limits in ground water and may cause various health problems (early symptoms of dental and skeletal fluorosis).
9. Phytoplanktons (*Euglena*, *Chlorella*, *Cosmarium* and *Navicula*) and zooplanktons (*Daphnia*, *Moina*, *Brachionus* and *Diaptomus*) have been noted dominated that indicate water pollution.
10. The number of *E. coli* exceeds the permissible limits in well and pond water. As a result, water has become a formidable factor in disease transmission and indicates the chance of pathogenicity.
11. Water born diseases such as anemia, diarrhea, cardiac problems, gastrointestinal disorder and skeletal problems have been found in town Deeg.
12. Ground water of Goverdhan and Kaman road is not potable due to high TH, fluoride, nitrate, TDS, chloride, salinity and *E. coli* as compared to Nagar road and Jal mahal area.
13. PHED supply water (all areas) is very hard and saline.
14. Pond water (all areas) is highly polluted and shows eutrophication (due to low DO, high COD/BOD, high phosphorous, turbidity, *E. coli* and phytoplankton) and not fit for any use.

Due to the physico–chemical parameters (turbidity, NO_3, P, fluoride, TH, alkalinity, DO, BOD and COD), *E. coli* and planktons which have been revealed beyond the acceptable limits, the water of town Deeg is not fit for potable and other purposes if used without any treatment. Management and conservation measures must be implemented to improve the water quality. The further study such as the estimation of trace elements (Cd, As, Zn, Iron, Pb) and pesticides will definitely be fruitful in improving the potability of water in town Deeg (Bharatpur).