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Impact of land use on quality of surface water in a hilly watershed

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■ **ABSTRACT :** Surface water flows through various land uses on its course before it is used for domestic as well as for livestock consumption. Physio–chemical as well as biological properties of surface water are affected by weathering of parent rocks, constituents of rainwater and anthropogenic activities. In simple term, it can be said that natural and manmade activities operating in the catchment govern the quality of water to a great extent. The present study was conducted to study the effect of different land uses and human interventions on different parameters of water quality. Surface water samples from five most prevalent land uses in the region ***viz.,*** forest, low land paddy, agricultural fallow, agriculture on bench terrace and *Bun* system of agriculture were collected periodically during monsoon season of 2008 and analysed for physio–chemical and biological properties. Average value of pH of water from all the land uses was acidic in nature. However, pH value of water from forest land use falls within the permissible limit prescribed by World Health Organization (1984) for drinking water standards. Other parameters such as conductivity, total dissolved salts, total alkalinity and hardness were within the maximum limits under all the land uses. Sodium was found to be dominant with its highest concentration of 148.77 ppm than other cations; calcium, magnesium, and potassium. However, concentration of all the cations in water samples of all the land uses was within the permissible limits. Concentration of nitrate (except in the water samples from agriculture land use on bench terrace) and phosphate in all the land uses was higher than the permissible limit of 45 and 2-3 ppm, respectively prescribed by Environmental Protection Agency (EPA, 1976) from water environment protection point of view but their concentration was below the WHO standards (1984) for drinking water. Iron content in the surface water from all the land uses except forest land use exceeded the maximum permissible limit prescribed by WHO for potable use of water. Faecal Coliforms (FC) was found in all the water samples however, water from forest land use contained minimum FC with its average number of 4 MPN/100ml. Surface water from forest land use can be used for drinking water purpose with mild treatments for FC. Considering the concentration of plant nutrients, runoff water from other land uses was found to be good for irrigation and fish rearing. Harvested water needs to be treated with lime to reduce the pH.

■ **KEY WORDS :** Hilly watershed, Land use, Standards for drinking water, Surface runoff, Water quality

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Meghalaya receives average annual rainfall of about 1900 mm but scarcity of water for human and livestock consumption is severely felt during winter period. Perennial and seasonal streams are the lifeline of the rural tribal population of the state. Therefore, level of presence of pollutants in the surface water assumes significant importance for deciding the extent of pollution or degradation of water environment. When sources of water pollution are enumerated, agriculture has been identified as a major contributor of non-point source of pollution of water resources. Agricultural pollutants (such as sediment, fertilizers, pesticides, salts or trace elements) resulting from various agricultural activities cause the degradation of surface and groundwater resources through soil erosion, chemical runoff, and leaching (Corbett *et al*., 1997; Thorburn *et al*., 2003). The quality of surface water will be modified by many factors such as its flow regime, climatic conditions, pH, land use practices, and topography of the catchments in addition to the various human interventions in the basin (Meybeck *et al*., 1990). In Meghalaya the main source of protected water supply is streams, which passes through different land uses along the hill slope, the quality of which depends upon the concentration of inorganic and organic constituents generated by natural as well as anthropogenic activities. Increase in

Table A : Geomorphological details of the study watershed

Sr. No.	Watershed notations	Area (ha)	Relief (m)	Slope (%)	Major land use
1.	MW	240.56	340	29.2	Grass land, low land paddy, and forest.
2.	WS_1	12.77	42	14.2	Grass land
3.	WS_2	10.69	36	14.1	Agriculture on bench terrace
4.	WS_3	2.08	24	20.5	Agriculture on bun
5.	WS_4	2.53	24	9.6	Agriculture on bench terrace and bun
6.	WS_5	1.06	26	18.6	Forest

human and bovine population, and subsequent pressure on land to sustain life is bringing more and more area under cultivation and thus deteriorating the water environment in the region. The present study was undertaken with objective to quantify the various water quality parameters as affected by different land use and anthropogenic activities.

METHODOLOGY

Study area :

Study site is located between 26^0 42' 34'' N and 25^0 43' 51'' N latitude and 91^0 67' 28'' E and 91^0 68' 41'' E longitude in Umsning block in Meghalaya state. The mean annual rainfall in the area is 1894 mm with more than 88 per cent occurring during the period from May to October. The daily mean temperature ranges from a minimum of 11.2^{0}C to a maximum of 24.7^{0}C. The soil of the experimental watershed belongs to the Typic Paleudalf with clay loam texture, pH 5.4 to 6.2, organic carbon 1.3 to 1.7 per cent with its content decreasing with depth. Geomorphological details of study watershed are presented in Table A.

Sample collection and analysis :

The surface water samples from distinct land uses, *viz.*, forest, lowland paddy, agricultural fallow, agriculture on bench terrace, and bun system of agriculture within the watershed were collected during the monsoon season of 2008. Samples for bacteriological analysis were collected in sterilized glass bottles and those for physio–chemical parameters in clean plastic bottles (Greenberg *et al.*, 1985). The samples were analysed for different physical, chemical and bacteriological parameters by standard methods (APHA, 1985). Phosphate and iron were estimated colorimetrically by a UV visible spectrophotometer (Model- Systronics – 119), after filtration of water through 0.45 mm millipore membrane filter paper. Chlorides, total alkalinity, and total hardness were determined by titration methods (Greenberg *et al.*, 1985). Nitrate were analysed by automatic N – analyser "KEL PLUS", K by flame photometer (Systronics – 128), and Phosphate by UV – VIS Spectrophotometer (Model- Systronics – 119). Water samples for cation (sodium, calcium and magnesium) were analysed using Metrohm Ion Chromatograph (Behera *et al.*, 2006). The bacterial quality of the water was determined by most probable number (MPN) method as per the World Health Organization manual (WHO, 1984) on international standards for drinking water and the presence of faecal coliforms (FC) was confirmed by spread plate method in triplicate from the tubes showing positive reaction and average value was taken. FC was enumerated on the same agar with colony morphology, 2 – 3 mm in diameter and red in colour.

RESULTS AND DISCUSSION

Water quality standards for drinking water (Bureau of Indian Standards, 1992; WHO, 1984) and the results of physio–chemical and bacteriological analysis of the surface water from different land use are presented in Table 1.

pH :

The average pH of surface water from all the land uses were acidic nature and ranged from lowest of 5.3 in agricultural field to highest of 6.4 in forest land use. The variation in pH values may be attributed to chemical composition of parent rocks from which soil is formed due to natural weathering, and also to the addition of fertilizers by farmers. Farmers applied fertilizers @ N=40, P=30 kg ha^{-1} in paddy and @ N=50, P=30 kg ha^{-1} maize only once during the cropping period. However, pH of water from all the land uses was found within the permissible limit of 6.5–8.5. However, the pH of surface water from forest was very close to the permissible limit. During peak of the monsoon season nature of the water remained acidic but pH values were slightly higher, which may be due to dilution effect due to rainwater. Therefore, surface water harvested from all the land uses were suitable for fish rearing with addition of any amendments to enhance the pH such as lime.

Conductivity :

Conductivity of water samples of all the land uses was tested to be very low with its average value ranging from a minimum of 18.2 for fallow land to a maximum of 71.1μ mhos/ cm for low land paddy. In upland cultivation, about 40 per cent of the flow is due to subsurface flow. Even after end of the storm subsurface flow continues and may act as cleansing of the salts, thus lowering the conductivity of the water received from land use on upland. In case of all the land uses, average conductivity of the surface water was found to be much lower than the desirable limit of 1500 µmhos/cm.

Alkalinity:

Phenolphthalein alkalinity of water samples from all the land uses was found to be below detectable limit while average total alkalinity varied from 12.0 to 23.0 mg/l which is much less than the desirable limit of 200 mg/l (Bureau of Indian Standards, 1992; WHO, 1984). Temporal variation during monsoon season was not noticeable. Total alkalinity is caused only by the bicarbonates and determines the eutrophic nature of the water body (Singh *et al*., 2003). Water bodies with alkalinity values > 100 mg/l is considered to be nutritionally rich (Alikunhi, 1957; Philipose, 1960). Water with low alkalinity is very much suitable for fish rearing with mild lime treatment.

Total hardness:

The degree of hardness of water is determined by the amount of calcium and magnesium salts present in it and it is most commonly used yardstick for assessing the quality of domestic supply water. Total hardness of water in all the land uses was tested very low with its average value of 3.0 in fallow land use to 26.5 mg/l for agricultural field, which was less than desirable limit of 300 mg/l. This clearly implies presence of low amount of salts in runoff water.

Turbidity:

Surface water from all the land uses was varied from slight turbid in forest land use (6 NTU) to turbid in other land uses during peak period of monsoon. The values of turbidity ranged from 6 to 16 NTU may be because of suspended soil particles due to soil erosion.

Total dissolved salts:

Aesthetic values as well as physio–chemical and biological properties of water are greatly attributed to the total amount of dissolved salts present in it. The average amount of total dissolved salts ranged as low as 2.18 in water samples from forest land use to as high as 16.98 mg/l from bun-cultivated field.

Sulphate and phosphate:

In general, these elements occur in all natural water. The sources of these in surface water may be chemical composition of the parent bedrock (John and Priscu, 2002) and addition in soil due to application of fertilizers. Phosphorous is also released from dead cells of plants and animals. They are vital plant nutrients. Average concentration of sulphate varied from 2.0 to 4.0 mg/l while that of phosphate ranged from 0.16 to 0.49 mg/l. From viewpoint of phosphate contents, the water from all the land uses can be considered as nutrient rich. Phosphate content of 0.05 mg/l is considered to be the maximum limit (EPA, 1976) from safe water environment view point. This limit may also be considered as one of the criteria for identification and prioritisation of critical sub watershed. Phosphate concentration more than this limit in stagnant water like pond, may enhance eutrophication. High content of phosphate in the surface water may also be attributed to the burning of forest and vegetation for practicing bun cultivation in the area.

Table 1 : Quality of surface water from different land uses and standards for drinking water

Parameters	Forest	Low land paddy	Fallow	Agriculture on bench terrace	Agriculture on bun	Desirable limit
pH	6.4	5.8	6.1	5.3	5.7	6.5 – 8.5
Conductivity (µ mhos/cm)	19.5	71.1	18.2	24.5	28.5	1500
Chloride (mg/l)	1.65	3.63	2.00	4.31	2.98	250
Turbidity (NTU)	6	16	10	12	16	5.00
Total dissolved salts (mg/l)	2.18	6.28	5.91	10.5	16.9	500
Total hardness (mg/l)	5.01	20.0	3.0	26.5	10.0	300
Calcium (mg/l)	1.49	1.18	2.06	1.04	2.52	200
Magnesium (mg/l)	1.23	1.00	-	1.21	1.10	200
Total alkalinity (mg/l)	12.0	16.5	23.0	14.5	13.2	200
Nitrate-N (mg/l)	8.80	20.16	3.84	11.30	9.04	45
Sulphate (mg/l)	2.0	3.0	2.0	4.0	3.0	200
Iron (mg/l)	0.12	0.64	0.36	0.42	0.64	0.3
Sodium (mg/l)	18.40	86.60	12.30	148.77	137.01	-
Potassium (mg/l)	72.6	57.3	44.0	24.9	66.8	-
Phosphorous (mg/l)	0.16	0.45	0.27	0.40	0.49	2 - 3
Faecal coliform (MPN/100ml)	4	75	9	54	41	Nil

All the values presented in the table represent average over the monsoon season of 2008

Nitrate:

Nitrate also is a vital plant nutrient. The sources of nitrate in surface water may be due to anthropogenic activities such as application of fertilizers in agricultural fields and very less due to biological degradation (Sawyer and McCarty, 1978). The average concentration of nitrate in runoff water varied from 3.84 from fallow land use to 20.16 mg/l from low land paddy land use. The variation in amount of nitrate in runoff from different land use may be attributed to the fact that amount of available nitrogen in soil of study site varied greatly. Soil analysis showed that available nitrogen in low land paddy field was 321 kg ha^{-1} while in upland soil available nitrogen was found to be 136 kg ha^{-1}. Non-point source pollution from agricultural field is quite evident as quantum of nitrate and phosphate in the runoff water from agricultural field is quite high and exceeds the maximum permissible limit of 10 mg/l and 0.01 mg/l, respectively (Mc Cutcheon *et al*., 1993). These non-point source pollutants are responsible for degradation of ecology of water environment. Nutrients concentration in the runoff water from low land paddy field is high as compared to the other land uses, which is attributed to high fertility status of paddy field due to decomposition of the biomass.

Potassium:

The average amount of potassium in runoff water varied from 24.9 mg/l from terraced agricultural field to 72.6 mg/l from forest land use. Potassium may not contribute significantly to non-point source pollution of ecology of water environment as its quantum in the runoff water from all the land uses was found to be well below the critical limit of 250 mg/l (WHO, 1984). But loss of potassium may affect the growth and yield of crop adversely.

Iron:

The average amount of iron in runoff water from all the land uses except forest land use was found to be slightly high. Its concentration varied from lowest of 0.12 mg/l from forestland to highest of 0.64 mg/l from low land paddy field. Though iron is one of the plant micronutrients but its higher concentration in stagnant water like in paddy field may affect paddy yield adversely. Therefore, periodic flushing of paddy field is necessary to obtain optimum yield. For drinking water purpose, iron content in surface water from forest is below the permissible limit of 0.3 mg/l prescribed by World Health Organisation (1984). The source of iron in the runoff water may be the parent rock.

Calcium, magnesium and sodium:

The average concentration of these cations detected in the runoff water from all the land uses is very low. However, concentration of sodium was dominant among these cations with its average concentration ranging from as high as 148 mg/l from agricultural field to as low as 18.4 mg/l from forest land. Concentration of calcium ranged from 1.18 to 2.52 mg/l while amount of magnesium was found to be varying from trace to 1.23 mg/l. The low concentration of calcium and magnesium is also evident from low amount of total hardness in the runoff water from all the land use. Generally, calcium and magnesium dissolves out of the parent rocks and contribute to the water environment.

Faecal coliforms:

Average count of faecal coliform present in runoff water ranged from 4 to 75 MPN/100 ml. In the beginning of the monsoon, the count was higher sometimes as high as 460 MPN/100 ml. This may be due to the fact that farmers apply animal waste as manure for *Kharif* crops. Also there is tradition in the area to free all the animals during winter for unrestricted grazing. Surface water samples collected during recession of monsoon showed lesser FC counts, sometimes as low as less than 3 MPN/100 ml in case of forest land use. These observations indicate reasonable safety of the water for potable use with mild level of treatment, particularly in case of the later part of monsoon water.

Conclusion:

Surface water flowing from all the land uses was acidic in nature with maximum average value of pH of 6.4. Total dissolved salts were found to be very low. Among cations, sodium was most dominant with its concentration varying from 12.30 to 148.77 mg/l. Total alkalinity and total hardness were much below the maximum permissible limit prescribed by World Health Organisation (WHO, 1984) for drinking water standards. Plant nutrients like phosphorous and nitrate exceeded the limit prescribed by Environmental Protection Agency (EPA, 1976) for non-point source pollution. These anions may cause pollution to water environment by causing eutrophication of water bodies. Average concentration of iron and faecal coliforms in surface water from all the land uses exceeded the prescribed limit (WHO, 1984) for drinking water. Average concentration of different water quality parameters showed that runoff water from all the land uses considered in the study is good for fish rearing with mild lime treatment and nutritionally rich for life saving irrigation of winter season crops. Surface water from forest land use can be used for drinking purpose with mild treatment for faecal coliforms.

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