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Water quality index and human health risk: a case study on Surma river

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Abstract

The study involves extensive laboratory tests to determine the physical and chemical parameters of the Surma river water, the values of which were used to calculate the water quality index and health risk. These parameters were Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Solids (TS), Ammonium Nitrate (AN) and pH. Water samples were collected at different points along the Surma river for both dry and wet seasons. Samples were analyzed for the above parameters and using the average dry and wet season values of these parameters, an expression of Water Quality Index (WQI) was developed. Moreover, risk has been calculated for the same by Hazard Quotient (HQ). The values of WQI were found to be 73.37 for dry season and 73.51 for wet season. HQ for Cu only was found to be 0.1788. The study concluded that the Surma river water was slightly polluted and no health risk was imminent at that time.

Keywords: Water parameters, WQI, HQ

Introduction

Quality of human environment is largely dependent on the availability of water, which is unique to our planet. Industrial development, improvements in living standards and change in agricultural practice has resulted in an increased demand for good quality water. However, such developments have produced increased amount of sewage, industrial wastewater, agricultural discharge, and agricultural runoff. The rivers that flow through almost all of the world's cities show an appreciable decline in water quality but it is often difficult to specify the exact cause of the deterioration.

Department of Environment (DoE) (1993) showed that the surface water quality of the country is moderately polluted at different locations. Their results were based on information gathered from 1981 to 1990. Of the sites, 11 were primary points that have been regularly sampled since 1980. Some sites are Global Environmental Monitoring System (GEMS) points, the results of which are forwarded to Nairobi for international monitoring. GEMS point no.6 is on Surma river in the upper Meghna catchment.

Surma is one of the biggest rivers of the North-Eastern zone of Bangladesh. The Chatak to Sunamganj river portion is primarily significant due to the presence of two major industries- the paper mill and the cement factory- although the effects from the paper mill are just a legacy now. The other significant feature is the conveyors that travel from India (Assam) to Chatak carrying stones to be transported to various parts of Bangladesh. These are quite large in number and currently the most visible polluting source of Surma at Chatak. There is hardly any study conducted on the quality of Surma (Chatak) river water.

The selected water quality parameters are important in determining the quality of Surma river water and hence are chosen due to the following reasons: the pH of an aqueous system is a measure of the acid-base equilibrium achieved by various dissolved components. Although it usually has no direct impact on consumers, it is one of the most important operational water quality parameters. Dissolved Oxygen (DO) content in surface water depends on the amount and characteristics of the unstable organic matters in the water. It is an important factor in assessing the self-purification capacity of polluted streams. Biochemical Oxygen Demand (BOD) is the amount of oxygen required by micro-organisms while stabilizing decomposable organic matter under aerobic conditions. It is the major criterion used in stream pollution control where organic loading must be restricted to maintain desired dissolved oxygen levels. Chemical Oxygen Demand (COD) is the measure of the biologically inert organic matter. The presence of Nitrate often stimulates the growth of algae to an undesirable extent. It is toxic and when present in excessive amounts, may cause methamoglobinaemia in infants. Total Solids (TS) is the combination of dissolved and suspended solids. The presence of these solids in surface waters is objectionable aesthetically and also because they adsorb chemical and biological agents, some of which are disease causing. The presence of these also makes the water turbid which affects the aquatic life.

Considering the pollution scenario of the Chatak Surma river, the above mentioned water quality parameters were used in developing the WQI and determining the HQ of Surma river water.

Materials and Methods

In this paper, in order to convey the data more simply, an attempt has been made to produce just a number which have been designed to integrate the data pool. Such numbers are called water quality indices (WQI). All indexing systems require measurements to be made for a selection of water quality parameters. Standard methods were adopted for the analysis of various water quality parameters (APHA-AWWA-WPCF, 1989). Concentration of Copper, Calcium and Cadmium were measured by flame Atomic Absorption Spectrophotometer.

WQI for Surma river water

A Water Quality Index (WQI) relates a group of water quality parameters to common scale and combines them into a single number in accordance with a chosen method or model of computation (Ahmed, 1999). For this particular WQI, a sub-index rating value was obtained for each parameter from a rating curve. These values were then aggregated to produce the final index score.

WQI was calculated from the following relation:

$$WQI = 0.22 \times SI \text{ of } DO + 0.19 \times SI \text{ of } BOD + 0.16 \times SI \text{ of } COD + 0.15 \times SI \text{ of } AN + 0.16 \times SI \text{ of } TS + 0.12 \times SI \text{ of } pH;$$

Where, SI is the sub-index of each parameter.

The water quality parameters for Surma river were determined as in Muyen et.al.(2003) and is given in Table 1. For the average values of each of the parameters in Table 1, the following SI values were obtained from the sub-index standard curves:

SI for DO- 5 (dry) and 5 (wet); SI for BOD- 99 (dry) and 100 (wet); SI for COD- 99 (dry) and 99 (wet); SI for AN- 98.5 (dry) and 99 (wet); SI for TS-100 (dry) and 100 (wet); SI for pH- 57 (dry) and 56 (wet)

The WQI thus obtained is usually compared to the value in a general rating scale (Ahmed, 1999) to use it as a preliminary means of assessment of a water body for compliance with the standards adopted for beneficial uses.

Moreover, risk has been calculated from Surma river water by hazard quotient (HQ).

Hazard quotient (HQ)

From field survey observations, the exposure pathways identified in Surma River were ingestion of fish, dermal contact with water and sediment, and residential ingestion of river water. Risk and hazards through inhalation of volatile materials were not assessed because these pathways are generally omitted for river water health risk assessment (EPA, 2001). But the trace metal was measured and found to be of a concentration of Ca: 2.38-12.38 ppm, Cu:<4ppb and Cd:< 4.6 ppb respectively. Hazard quotient was measured for these values of the metals.

The non-cancer health threat is evaluated by the calculation of a hazard quotient (HQ), where possible, for each pollutant, via each route of exposure within each exposure scenario. Each hazard quotient is calculated as follows: HQ = CDI /RfD. Where, CDI = appropriate calculated route specific dose; RfD = appropriate route-specific reference dose for the toxicant expressed in mg/kg-day.

For a single chemical, if the HQ > 1, this indicates that the dose exceeds the RfD. The RfD is a conservative value, usually based on animal studies, deliberately set low to be maximally protective of human health in the regulatory setting.

The HQs are then added together in various ways to assess potential combined effects of pesticide active ingredient exposure by calculating hazard indices (HIs). Each chemical-specific and scenario-specific HI is calculated as follows:

$$HI = HQ_O + HQ_D + HQ_I$$

where, HQ_O = HQ for oral exposure; HQ_D = HQ for dermal exposure; HQ_I = HQ for inhalation exposure.

For the quantification of potential human exposure in relation to the contamination by above parameters as well as heavy metal of the sediment of river flood plain the following equations were used:

CDI calculation from ingestion of sediment = $(C_s \times IR_s \times EF \times AF)/BW$
CDI calculation from surface water = $(C_w \times IR_w \times EF \times AF)/BW$
CDI calculation from suspended matter = $(C_M \times C_{MW} \times IR_W \times EF \times AF)/BW$
CDI calculation from dermal contact with surface water =
$(C_W \times SA_W \times AS_W \times EF \times ED_W \times EF)/BW$
And sediment = $(C_s \times SA_s \times AD \times AS_s \times M_f \times ED_s \times EF \times AF)/BW$

Where, SA_W = dermal surface contact from exposure in water ($1.8m^2$)
AS_W = dermal absorption (cm/hr) (0.005 cm/hr)
IR = ingestion rate
AF = absorption factor (1)
EF = exposure frequency (30 days)
BW = body weight (70kg)
C_M = concentration of pollutants in total suspended solid (mg/l)
C_{MW} = total suspended matter in surface water
AD = dermal adherence rate for sediment (mg/cm^2)
AS_s = dermal absorption rate for sediment (l/hr) (0.005)
M_f = molecular weight (g/mol) (0.15)
C_s = concentration of pollutant in sediment (mg/kg)
SA_s = dermal surface contact from exposure in sediment ($0.28m^2$)
ED = exposure duration (hr/day) (1)

The above formula have been obtained from Albering *et al.* (1999)

Results and Discussion

The water quality parameters for Surma river were determined as in Muyen *et.al.* (2003) and given in Table 1.

Table 1. Statistical analysis of water quality parameters of Surma river

	DO mg/l		BOD mg/l		COD mg/l		pH		TS mg/l		AN mg/l	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Mean	5.52	5.72	1.00	0.88	1.53	1.34	6.13	6.09	149.40	145.70	0.18	0.12
Std. Deviation	1.40	1.42	0.38	0.31	0.52	0.40	0.29	0.33	38.62	38.52	0.09	0.07
Variance	1.98	2.01	0.14	0.10	0.27	0.16	0.08	0.11	1491.82	1483.8	0.01	.005
Minimum	3.50	3.60	0.60	.60	1.00	0.90	5.86	5.70	100.00	95.00	0.08	0.04
Maximum	7.20	7.60	1.80	1.60	2.60	2.00	6.86	6.90	230.00	224.00	0.35	0.23

It was found that, in the case of DO, standard for sustaining aquatic life is 4mg/l whereas for drinking purposes it is 6mg/l. DO value for Surma river (Chatak to Sunamganj) lies in between 5.52mg/l (dry) to 5.72mg/l (wet). While in the case of BOD, the standard for drinking purpose is 0.2mg/l, which exceeded to a great extent as shown by the mean values (dry-1mg/l, wet-0.878mg/l). COD is another important parameter whose standard for drinking purpose is 4mg/l, thus acceptable. pH is an indicator of acidic or alkaline water. The standard for any purpose in-terms of pH is 6.5-8.5, in that respect; the mean value (dry-6.126, wet-6.093) indicates slightly acidic Surma river water.

WQI for dry season was found to be 73.37 and that for wet season was 73.51. The rating scale (Ahmed, 1999) used in relation to this particular Indexing system termed Surma river water 'slightly polluted'.

Only Cu was found in suspended matter. CDI value was calculated due to suspended matter which was 0.0005364 mg/kg-day. HQ value was found to be 0.1788. In terms of HQ, if it is greater than one, this indicates that the dose exceeds the RfD. Human exposure at or above the RfD, while noteworthy, does not necessarily mean that there will be any real negative impact on human health (Albering *et al*,1999).

Studies conducted on the part of Surma flowing through the Sylhet city & its surrounding area by Hossain (2001), Shiddiky (2002) involved the water quality parameters like, metal ions, and pH, DO, BOD and Total Dissolved Solids (TDS) .They reported that, 510 of the water samples out of 611 had pH ranges from 6.5to7.2. TDS of all water samples were far higher than the accepted level, which indicates decreased rate of sunlight penetration into the water, resulting in decreasing phytoplankton growth, which ultimately affects the sound growth of aquatic lives. However, the pollution scenario of the two portions of Surma river is found to be similar.

The values of WQI were found to be 73.37 for dry season and 73.51 for wet season. HQ for Cu only was found to be 0.1788. So, the present state of Surma river water can be said to be slightly polluted with no particular risk to human health yet, since the HQ value does not exceed 1(Albering *et al*, 1999).

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