Economic Costs of Water Pollution on Rural Livelihood

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Introduction

A growing world population, unrelenting urbanization and increasing developmental activities have accelerated the demand for water. While the global water supply is fixed, the multisectoral demand for water has been growing over the years. Agriculture is the biggest water user, with irrigation accounting for 70 per cent of global water withdrawals. Agricultural water consumption is expected to increase globally by about 20 per cent by 2050 (Anonymous, 2014). Increasing demand and finite supply have put pressure on water management and compromised on water quality. Global water, irrespective of the sources is polluted affecting many productive activities of human society. Various water sources across globe like rivers, ponds, lakes and streams and wells are polluted due to anthropogenic factors.

According to the Indian Water Act, 1974 (Prevention & Control of Pollution), pollution of water is defined as "contamination of water or such alteration of the physical, chemical or biological water or such discharge of any other liquid, gaseous or solid substance into water (whether directly to indirectly) as may or is likely to create a nuisance or render such water harmful or injurious to public health or safety, or to domestic, commercial, industrial, agricultural or other legitimate uses or to the life and health of animals or plants or of aquatic organisms". World Health Organization (WHO) has defined water Pollution as inclusion of any foreign material either from natural or other sources into a water body, thereby changing the natural qualities of water and making it unusable for its intended purpose (Anonymous, 2004).

Poor quality of water adversely affects agriculture production, livestock and human health which, in turn, negatively affect agrarian economy and retards improvement in living conditions of rural people (Shivasharanappa and Yalkpalli, 2012). Polluted water can cause disease and health problems such as skin allergy, respiratory infections, general allergy, gastritis and ulcer. Polluted water had significant influence on these diseases (Govindarajalu, 2003). Diarrhoeal disease alone amounts to an estimated 4.1 per cent of the total Disability-Adjusted Life-Year (DALY) global burden of disease and is responsible for death of 1.8 million people every year. About 88 per cent of that burden is attributable to unsafe water supply, sanitation and hygiene and is mostly concentrated on children in developing countries (Anonymous, 2004).

There is a general debate going on in the world as well as in India on the health of rivers and their negative impacts on agriculture and rural livelihoods. Health of Indian river is severely affected due to pollution from different sources and in some cases rivers have lost their genuine natural characteristics. Water pollution has emerged as an important issue in India as most of the rivers are polluted. Most of the Indian rivers and their tributaries viz., Ganges, Yamuna, Godavari, Krishna, Sone, Cauvery, Damodar and Brahmaputra are reported to be grossly polluted due to discharge of untreated sewage disposal and industrial effluents directly into the rivers. These wastes usually contain a wide variety of organic and inorganic pollutants including solvents, oils, grease, plastics, plasticizers, phenols, heavy metals, pesticides and suspended solids. Indiscriminate dumping and release of wastes containing hazardous substances into rivers leads to environmental disturbance which could be considered as a potential source of stress to biotic community.

Many physico-chemical or agrobiological studies in the past have revealed the extent and type of pollution of water. But, ultimately it is impact of this pollution on economic activities which decide the crucial livelihoods of people. Therefore, the present study was taken up with an aim to analyse the impact of river water pollution on agriculture and rural livelihoods.

Methodology

Study was taken up in Bhima River which is one of the important tributaries of Krishna River in South India. Bhima flows southeast for long journey of 861 km during which many smaller rivers flow into it. Kundali, Kumandala, Ghod, Bhama, Indrayani, Mula, Mutha and Pavna are the major tributories of this river. Bhima River basin was purposively selected for the study in view of complaints from the local farmers and social activists around the region regarding emerging problems of pollution in Bhima River and their efforts.

To assess the effects of water quality, the study area was divided into two clusters namely, polluted villages and non polluted villages, based on the extent of effect of river water quality. A sample of five villages on the banks of river and another five villages away from the river but with similar agro economic conditions was selected. In the next stage, using stratified random sampling method, twelve farmers from each village belonging to different farm size categories namely, large farmer (> 5 acres), medium farmer (3–5 acres), small farmer (2–3 acres) (Reddy and Behera, 2005) and landless labourers in equal numbers were selected for data collection. Data needed for the study were collected from respondents by personal interview method using pre-tested schedule. A total of 120 sample farmers consisting of 60 from each cluster were chosen. To estimate the economic cost of river water pollution on agriculture and livestock detailed household level information regarding farming practices, crop production, yield levels, input and output policies, livestock, disease or other health problems of persons was collected.

To estimate water quality, water samples were collected from two polluted and two non polluted villages and tested in accredited laboratories, for parameters like electrical conductivity (EC), total dissolved solids (TDS), pH, total alkalinity, total hardness, chloride, sulphate, calcium, magnesium, Biological Oxygen Demand, Chemical Oxygen Demand, oil and grease, total suspended solids (TSS), phosphate, fluoride, turbidity, iron, arsenic, bacterial plate count, coliform count, and E.coli. Water samples were collected twice, once in pre-mansoon and second in post mansoon seasons. Results of water samples tests were compared with Indian and WHO standards of water quality.

Analytical tools and techniques employed

To fulfill objectives of the study tabular analysis, logistic regression and decomposition model were used. Tabular presentation method was used to present the agro biological characters of water samples.

Decomposition Model

Production function approach

Most of the farm studies have established that Indian agriculture would approximate the Cobb-Douglas type of production function (Heady and Dillon, 1964). Further, constant returns to scale is empirical evidence widely observed in studies on Indian agriculture. Both these were assumed for the present study and hence the per hectare production function in the Cobb-Douglas form was specified. It was aimed to decompose the change in productivity of a principal crop (sugarcane) between water polluted villages and water non polluted villages into the impact due to polluted water used for irrigation and that due to change in use of inputs. The Cobb-Douglas form of production function was used for yield in water polluted villages and water non polluted villages. Sugarcane was chosen for the study as it was a pre-dominant commercial crop in the region in terms of acreage. Specifications of the model are as follows;

For non polluted villages

$Y1 = a1\, X11^{b11} X12^{b12} \ldots\ldots\ldots\ldots\ldots\ldots\, X1n^{b1n} e$ _____________ (1)

For polluted villages

$Y2 = a2\, X21^{b21}\, X22^{b22} \ldots\ldots\ldots\ldots\ldots\ldots\, X2n^{b2n} e$ _____________ (2)

Where,

Y1 = Gross output obtained in non polluted villages

Y2 = Gross output obtained on polluted villages

a1 and a2 are the intercept of non polluted and polluted villages, respectively

X1n = Independent variables in non polluted villages

X2n = Independent variables in polluted villages

For sugarcane the independent variables included,

X1 = Seeds (quintal)

X2 = Organic manure (quintal)

X3 = Human labour (man days)

X4 = Bullock labour (pair days)

X5 = Plant protection chemicals (Rs. /ha)

X6 = No. of irrigations

bi = output elasticity co-efficient of i^{th} input

Taking logarithm on both sides for equations 1, and 2,

$\ln Y1 = \ln a1 + b11 \ln X11 + b12 \ln X12 \ldots\ldots\ldots\ldots\ldots\ldots + b1n \ln X1n$ __________ (3)

$\ln Y2 = \ln a2 + b21 \ln X21 + b22 \ln X22 \ldots\ldots\ldots\ldots\ldots\ldots + b2n \ln X2n$ __________ (4)

Decomposition model

To identify the structural break in the production relations that defined the yield levels in water polluted villages and water non polluted villages, a dummy variable with 1 for water polluted villages and zero for water non polluted villages was introduced in the production function of Cobb-Douglas setting. The decomposition model for polluted V/s non polluted water was obtained by taking difference between equation (3) and (4).

$(\ln Y2 - \ln Y1) = (\ln a2 - \ln a1) + \{(b21 \ln X21 - b11 \ln X11) + (b22 \ln X22 - b12 \ln X12) + \ldots\ldots\ldots\ldots\ldots + (b2n \ln X2n - b1n \ln X1n)$ _________ (5)

(Kiresur and Ichangi, 2011) (Mukkannawar, 2011)

Logistic regression

A logistic regression analysis was carried out to know the determinants of morbidity reported by the households. A dummy dependent variable assuming value 1 if the estimated household morbidity was greater than 0, that is the households report at least one sick member with skin itch, typhoid, diarrhea, fever which was major disease in the water polluted villages in reference period and otherwise zero has been generated. Explanatory variables were selected based on the assumption that the following attributes influenced whether households belonged to high or low risk categories. (1) location (proximity to wastewater) of households places them in high or low risk groups; (2) extent as well as type of exposure to (waste) water based livelihoods, (3) general hygienic and living conditions make some households more vulnerable to diseases than others; (4) socio-economic conditions of households which can influence the health status of the households and thereby morbidity.

$$L_i = \ln (P_i / 1 - P_i) = \beta_1 + \beta_2 \text{ Vil\_c} + \beta_3 \text{Ow\_land} + \beta_4 \text{Ow\_livestock} + \beta_5 \text{ Edu\_head} + \beta_6 \text{agri\_lab} + \beta_7 \text{family\_size} + \beta_8 \text{avg\_age} + \beta_9 \text{fuel} + \beta_{10} \text{mig\_lab} + \beta_{11} \text{caste} + \beta_{12} \text{pvt\_toilet}.$$

(Kiresur and Ichangi, 2011).

Table 1: Description of variables included in the logistic regression and their expected signs

Variables	Explanation	Expected sign	Attribute Represented
Vil_c	Whether the households belong to Village with polluted or non polluted water 1= Polluted; 0= otherwise	Positive	Exposure
Ow_land	Ownership of land 1= those owning land 0= otherwise	Negative	Socio economic and exposure
Ow_livestock	Ownership of livestock 1= Yes; 0 = otherwise	Positive	Exposure
Edu_head	Education of the head of the Household	Negative	Socioeconomic
agri_lab	Hired agricultural labour 1= Yes; 0= otherwise	Positive	Exposure
family_size	Total number of members in the Family	Positive	Socioeconomic
avg_age	Average age of the members in the Household	Positive	Vulnerability to Diseases
Fuel	Fuel used for cooking 1= solid fuel; 0= otherwise	Positive	Vulnerability to diseases and living conditions
mig_lab	Migrant labour 1= migrant labour; 0=otherwise	Positive	Exposure
Caste	Social group to which households belong to 1= SC/ST; 0= otherwise	Positive	Socioeconomic
Pvt_toilet.	Whether the households have private toilets or not 1= Yes; 0= Otherwise	Negative	Vulnerability to diseases and living conditions

(Reddy and Behera, 2005)

Results and Discussion

Table 2: Drinking water quality standards

Parameter	Acceptable limit
Total Dissolved Solids mg/l	500
pH	6.5-8.5
Total Alkalinity as CaCO3 mg/l	200
Total Hardness as CaCO3 mg/l	200
Chloride as Cl mg/l	250
Sulphate as SO4 mg/l	200
Calcium as Ca mg/l	75
Magnesium as Mg mg/l	30
Oil & grease mg/l	0.01
Fluoride as F mg/l	1
Turbidity NTU	5
Iron as Fe mg/l	0.3
Arsenic as As mg/l	0.01
BOD (mg/l)	2
COD (mg/l)	10
E. coli per 100 ml	Shall not be detectable in any 100 ml sample

Source: Indian Standards of water quality 10500: 2012 and WHO (2006)
*NTU = Nephelometric Turbidity Unit

Table 2 presents drinking water quality standards given by Indian and WHO Standards. Accordingly, desired limit of total dissolved solid (TDS) is 500 mg/l. TDS above desirable limit leads to decreased quality of palatability and may cause gastro intestinal irritations. Desired limit of pH is 6.5 to 8.5. Any value beyond this limit will affect mucus membrane and water supply system. Desirable limit for total alkalinity is 200 mg/l. Beyond this limit water taste becomes unpleasant. Desirable limit for total hardness is 200 mg/l and any value above this limit leads to encrustation in water supply structure and adversely effects domestic use. Desirable limit for chloride is 250 mg/l. Water with values beyond this limit, taste and palatability are affected. Desirable limit for calcium and magnesium is 75 mg/l and 30 mg/l, respectively. Values beyond these limit cause encrustation. Desirable limit for turbidity is 5 Naptholometric Furgibility Unit (NTU). Beyond this limit consumer's acceptance decreases. Desirable limit for iron is 0.3 mg/l beyond which taste, appearance are affected. These will create adverse effect on domestic use and water supply structures and promote iron bacteria. Desirable limit for arsenic is 0.01mg/l and beyond this limit water becomes toxic which leads to risk of cancer and skin damage. Desirable limit for mineral oil is 0.01 and beyond this limit water is undesirable in taste and odour. Desirable limit for fluoride is 1 mg/l and any value beyond this limit causes fluorosis. Desirable limit for COD is 10 mg/l. Higher level of COD value indicates that most of the pollution caused by industrial effluents upstream. Desirable standard for BOD is 2 mg/l. BOD gives an idea of the quantity of biodegradable organic matter present in an aquatic system which is subjected to aerobic decomposition by microbes. BOD provides direct measurement of the state of pollution (Shivasharanappa and Yalkpalli, 2012).

Results of water sample tests for drinking water

An analysis of degree of water of pollution involved comparisons across both space (clusters) and time (inter seasonal) against the Indian and International Standards (WHO) for selected parameters.

With respect to TDS safe the limit suggested by Indian Standards and WHO is 500 mg/l. As against this the average value for river and bore well water samples was 863.25 mg/l and 652.25 mg/l, respectively across the season. This indicated that when compared to the standards the values for both river and bore well samples were above the acceptable limits. An inter cluster analysis revealed that river water was more polluted compared to bore well water.

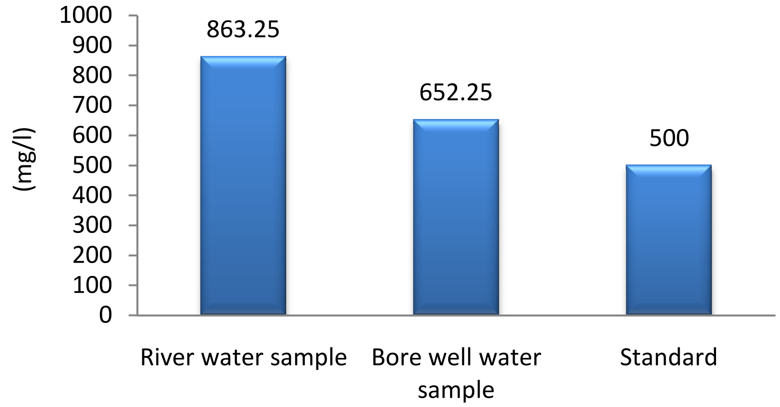

Fig.1 Total Dissolved Solid content in water samples (mg/l)

An inter seasonal comparison of both river and bore well samples was also made. Results revealed that among the river water samples, sample drawn during April (910 mg/l) had higher value compared to January sample (816.5 mg/l), which revealed that water samples were more polluted in summer compared to end of winter season.

The standard limit with respect to pH is 6.50 to 8.50. As against this, the average value for river and bore well water samples was 8.37 and 7.43, respectively over the seasons. This showed that when compared to standard limits the values for both river and bore well water samples were within the acceptable limits. An inter cluster analysis revealed that river water was more polluted compared to bore well water. An inter seasonal comparison of river and bore well samples showed that the river water samples in January had slightly higher pH samples drawn (8.40) compared to April samples (8.34).

With respect to total alkalinity the suggested standard is 200 mg/l. As against this, the average value for river and bore well water samples was 285.75 mg/l and 354.5 mg/l, respectively across the seasons. This indicated that in comparison to the standards, the values for both river and bore well samples were within acceptable limits. An inter cluster analysis revealed that river water had lower levels of alkalinity compared to bore well.

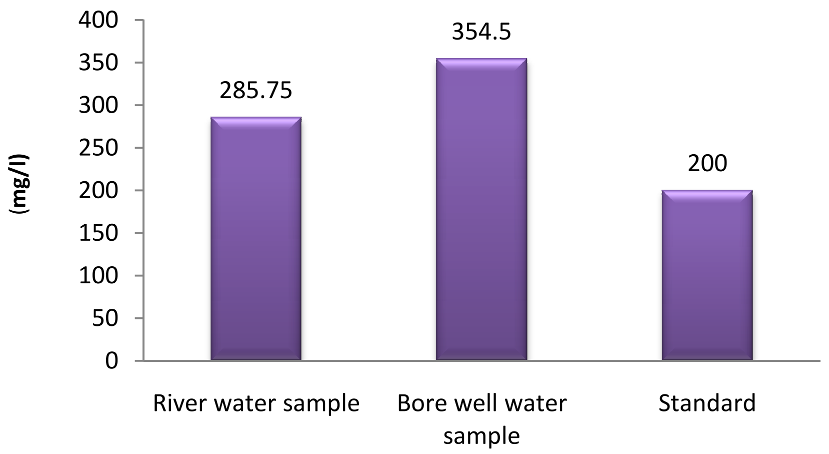

Fig. 2 Total Alkalinity as CaCO3 (mg/l) in water samples

With respect to total hardness the limits suggested by Indian and WHO standards is 200 mg/l. As against this, the average value for river and bore well water samples was 388.75 mg/l and 391.25, respectively over the seasons. This indicated that when compared to standard limits the values for both river and bore well samples were above the acceptable limits. An inter cluster analysis revealed that bore well water had higher levels of hardiness.

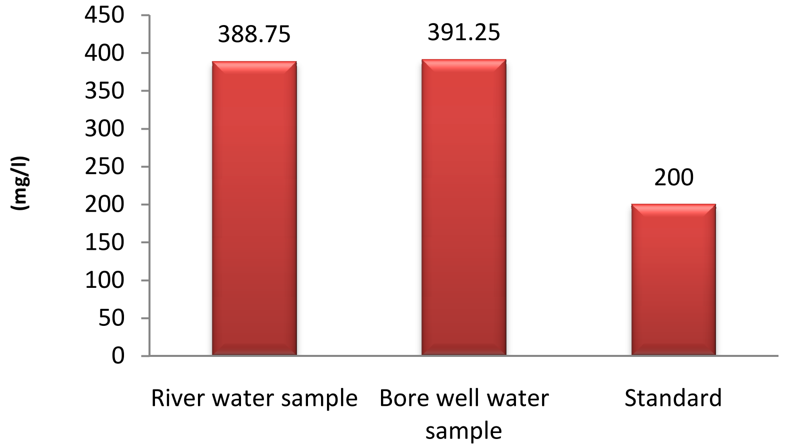

Fig. 3 Total Hardness as CaCO3 (mg/l) in water samples

An inter seasonal comparison of both river and bore well water samples revealed no significant differences in hardiness of water during January (399 mg/l) and April (378.5 mg/l). In case of bore well water hardness was more in January (490.5 mg/l) when compared to April sample (292 mg/l).

Standards chloride in water is 250 mg/l as against chloride. The average value for river water and bore well water was 272 mg/l and 156.78 mg/l, respectively over the seasons. When compared to the standard limit (250 mg/l) the values for river water was above the acceptable limit and value for bore well water was within acceptable limit.

An inter seasonal comparison of both river and bore well samples revealed that the river water drawn during April had higher value (297 mg/l) compared to January (247 mg/l).

With respect to the sulphate, the standard limit is 200 mg/l. The average value for river water sample over the season was 109.5 mg/l and for bore well water sample it was 57 mg/l over the seasons. This indicated that when compared to the standard limit (200 mg/l) for both river and bore well samples were well within the acceptable limits. As such levels of sulphur in water did not pose any problem.

With respect to the calcium the limits suggested by Indian standards and WHO was 75 mg/l. As against this the average values for river (84.75 mg/l) and bore well (94.75 mg/l) water sample the season across the season were found to be above the acceptable limits. An inter cluster analysis revealed that bore well water levels of calcium compared to river water.

An inter seasonal comparison of both river and bore well water sample revealed that among the river water samples, sample drawn during January (87.5 mg/l) had higher value compared to April sample (82 mg/l). In case of bore well water sample average value of calcium was double than that in January (120 mg/l) when compared to April sample (69.5 mg/l).

Acceptable limit for magnesium, according to the Indian standards and WHO is 30 mg/l. But, the average value of calcium in river and bore well samples over the seasons were 42 mg/l and 38.5 mg/l, which were above the standards.

An inter seasonal comparison of both river and bore well water samples revealed that the river water drawn during January (44 mg/l) had slightly higher value compared to April (40 mg/l) sample. In case of bore well water sample average value of magnesium was more in January (46.5 mg/l) compared to April (30.5 mg/l) sample.

The limits suggested by Indian standards and WHO for BOD is 2 mg/l. As against this the average value for river water sample was 2.10 mg/l and for bore well, it was 2.13 mg/l for bore well water sample over the season. This indicated that when compared to the standard limits the value for both river and bore well samples were above the acceptable limits. An inter cluster analysis revealed bore well water had slightly higher BOD level compared to that of river water.

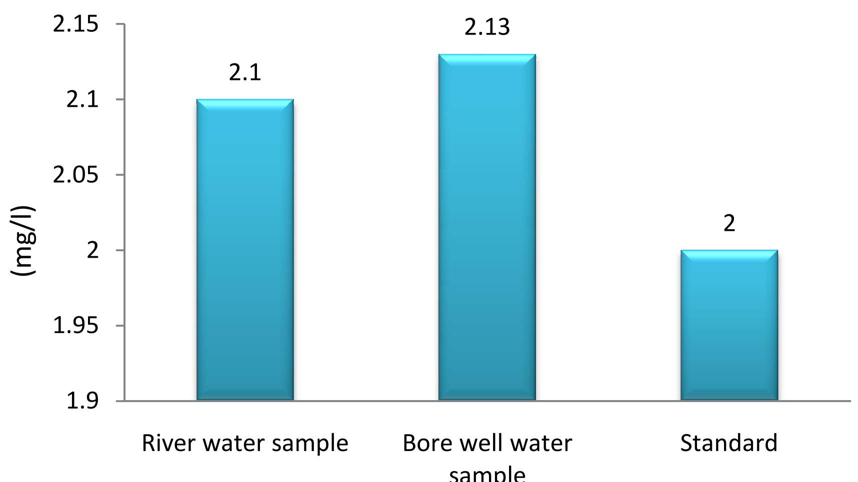

Fig. 4 Biological Oxygen Demand (mg/l) in water samples

An inter seasonal comparison of both river and bore well water samples revealed that the river water drawn during January had lower value (1.7 mg/l) compared to April sample (2.5 mg/l). In case of bore well water average value of BOD was more in January (2.65 mg/l) when compared to April (1.62 mg/l) sample.

The limit suggested by Indian and WHO standards with respect to COD was 10 mg/l. As against this, the average values for river and bore well water sample over the season was 6.3 mg/l and 6.7 mg/l for bore well water sample over the season. When compared to standard limits the value for both river and bore well water samples were within the acceptable limits. An inter cluster analysis revealed that bore well water was more polluted compared to river water.

An inter seasonal comparison of both river and bore well samples showed that among the river water samples, sample drawn during April (7.9 mg/l) had higher value compared to January (4.7 mg/l) sample. In case of bore well water sample average value of COD was more in January (8.35 mg/l) compared to April (5.05 mg/l) sample.

The limits suggested by Indian Standards and WHO with respect to oils and grease is 0.01 mg/l as against this value the average value for river water sample over the season was 0.45 mg/l and oil and grease was not detected in river water sample. This indicated that when compared to standard limits the value for river water sample was above acceptable limit. An inter cluster analysis revealed that river water was polluted and bore well water was not polluted.

An inter seasonal comparison of both river and bore well samples showed that among the river water samples, sample season during January (0.5 mg/l) had higher value compared to April (0.41 mg/l) sample. In case of bore well water oil and grease were not detected.

The limits suggested by Indian standard and WHO with respect to fluoride is 1 mg/l. As against this, the average value for river water sample was 0.15 mg/l and 0.39 mg/l for bore well water across the seasons. This indicated that when compared to the standard limits the values for both river and bore well water samples were within acceptable limit.

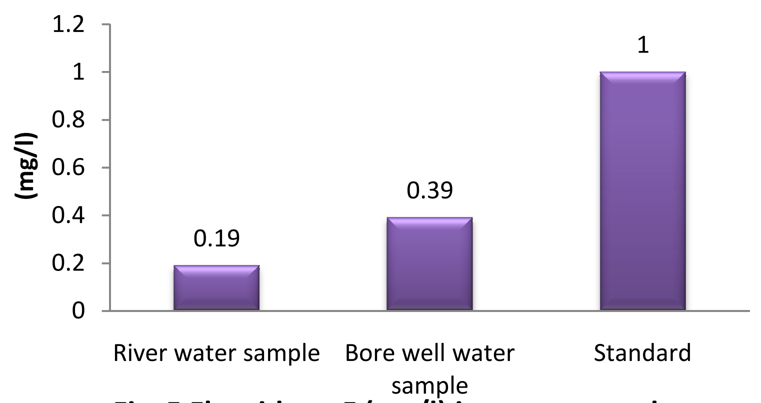

Fig. 5 Fluoride as F (mg/l) in water samples

With respect to turbidity, the limits suggested by Indian standards and WHO is 5 NTU. As against this, the average value for river water was 27.75 NTU and 3.3 NTU for bore well water sample across the season. This indicated that when compared to the standard limits the value for river water was above acceptable limit and that for bore well water was within acceptable limits.

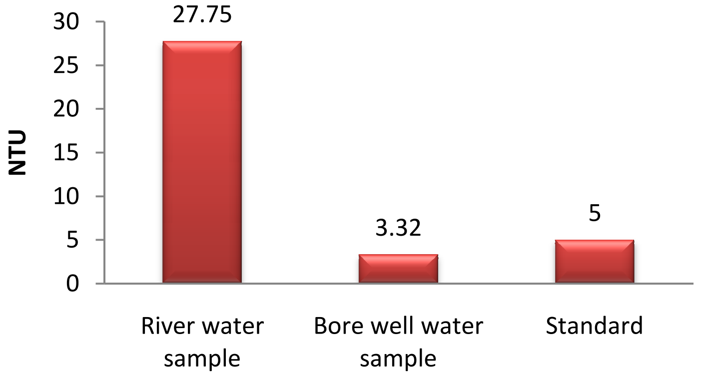

Fig. 6 Turbidity NTU in water samples

An inter seasonal comparison of both river and bore well water samples revealed that among the river water samples drawn during January (29.15 NTU) had higher value compared to April sample (26.35 NTU). In case of bore well water average value of turbidity was slightly less in January (2.65 NTU) when compared to April (4 NTU) values.

The limits suggested by Indian standards and WHO with respect to iron is 0.3 mg/l. The average value of iron content in river water was 0.13 mg / l and 0.07 mg/l in bore well water across the season. When compared to standard limits (0.3 mg/l) the values for both river and bore well samples were within acceptable limits. The iron content in water samples did not pose any challenge.

As against the standard norms for arsenic (0.01 mg/l) the average value for bore well water sample was 0.0375 whereas arsenic was not detectable in river water. However, caution is required regarding arsenic content in bore well water.

The limits suggested by Indian standards and WHO with respect to bacterial plate count (per 100 ml) is that bacterial shall not be detectable in any 100 ml sample. As against this, the average value for river and bore well was 335.5 and 135.75, respectively across the season. This indicated that both the samples of water were polluted but the extent of pollution was more in river water which would affect consumers of such water. An inter seasonal comparison of river water samples showed that samples drawn during April had higher value (401) compared to January value (270).

The standard norm for coliform count (per 100 ml) is that coliform shall not be detectable in any 100 ml sample. The average coliform count value was 3.75 and 1.75, respectively for river and bore well water samples across the seasons which indicated that river water was more polluted.

The limits suggested by Indian standards and WHO with respect to *E. Coli* (per 100 ml) is that *E. Coli* shall not be detectable in any 100 ml sample. The study findings revealed average value for river and bore well across water the seasons was 1.5 and 0.25, respectively. This indicated that when compared to the standard limits the value for river water sample was above acceptable limit.

There were no inter seasonal differences in the bacterial load. However, river water needs to properly purified before consumption.

Table 2: Results of water sample tests for drinking water

Parameter	Acceptable limit	River water sample							Bore well water sample						
		January		Average	APRIL		Average	Overall Average	January		Average	APRIL		Average	Overall Average
		S-I	S-II		S-I	S-II			S-III	S-IV		S-III	S-IV		
Total Dissolved Solids (mg/l)	500	1040	593	816.5	1110	710	910	863.25	534	1038	786	580	457	518.5	652.25
Ph	6.5-8.5	8.35	8.46	8.405	8.37	8.31	8.34	8.3725	7.3	7.21	7.255	7.47	7.74	7.605	7.43
Total Alkalinity as CaCO3 (mg/l)	200	332	267	299.5	304	240	272	285.75	350	494	422	296	278	287	354.5
Total Hardness as CaCO3 (mg/l)	200	490	308	399	445	312	378.5	388.75	368	613	490.5	332	252	292	391.25
Chloride as Cl (mg/l)	250	328	166	247	366	228	297	272	110	256	183	158	103	130.5	156.75
Sulphate as SO4 (mg/l)	200	125	54	89.5	175	84	129.5	109.5	29	118	73.5	34	47	40.5	57
Calcium as Ca (mg/l)	75	108	67	87.5	96	68	82	84.75	90	150	120	81	58	69.5	94.75
Magnesium as Mg (mg/l)	30	54	34	44	49	31	40	42	35	58	46.5	36	25	30.5	38.5
B.O.D (mg/l)	2	2	1.4	1.7	2.7	2.3	2.5	2.1	2.3	3	2.65	1.4	1.85	1.625	2.1375
C.O.D (mg/l)	10	5.6	3.8	4.7	7.8	8	7.9	6.3	7.4	9.3	8.35	5.1	5	5.05	6.7
Oil & grease (mg/l)	0.01	0.3	0.7	0.5	0.65	0.18	0.415	0.4575	0	0	0	0	0	0	0
Fluoride as F (mg/l)	1	0.1	0.12	0.11	0.18	0.2	0.19	0.15	0.37	0.45	0.41	0.46	0.31	0.385	0.3975
Turbidity NTU	5	21.2	37.1	29.15	32.1	20.6	26.35	27.75	3.9	1.4	2.65	4.8	3.2	4	3.325
Iron as Fe (mg/l)	0.3	0.14	0.09	0.115	0.17	0.13	0.15	0.1325	0.06	0.1	0.08	0.07	0.05	0.06	0.07
Arsenic as As (mg/l)	0.01	0	0	0	0	0	0	0	0	0.15	0.075	0	0	0	0.0375
Bacterial plate count (per 100 ml)	Shall not be detectable in any 100 ml sample	140	400	270	182	620	401	335.5	90	28	59	45	380	212.5	135.75
Coliform count (per 100 ml)	Do	3	6	4.5	2	4	3	3.75	2	1	1.5	1	3	2	1.75
E.Coli (per 100 ml)	Do	1	2	1.5	1	2	1.5	1.5	0	0	0	0	1	0.5	0.25
Yeast & mould count (per ml)	Do	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Irrigation water quality

Irrigation consumes almost 70 per cent of available water and as such its quality aspects assume importance. Poor quality irrigation water can affect productivity and soil health. Untreated or partially treated wastewater, which is a negative externality of urban water use, is widely used for irrigation in water scarce regions in several countries including India. While the nutrients contained in the wastewater is considered as beneficial to agriculture, the contaminants present in it pose environmental and health risks (Srinivasan and Reddy, 2009**).** Reddy and Behera (2005) analyzed the economic impact of water pollution on rural communities in Patancheru, Jeedimetla and Bollarum industrial regions of Andhra Pradesh and reported that about 45 ha of cultivable land became uncultivable by soil pollution due to irrigation with polluted water in the study villages. Paul and Nelliyat (2006) studied compensating the loss of ecosystem services due to pollution in Noyyal river basin, Tamil Nadu. Study revealed that in the severely affected areas farmers did not cultivate paddy and the study estimated the loss of not cultivating paddy. Khai and Yabe (2012) studied rice yield loss due to industrial water pollution in Vietnam. The results showed that the productivity loss was about 0.57-0.75 tons per hectare. Thus, findings of several studies suggest that irrigation with polluted water results in economic losses.

Table 3: Irrigation water quality in terms of the electrical conductivity (mS/cm)

Results	**River water**		**Average**	**Borewell water**		**Average**	**Difference**
	Dhulakhed	**Bhuyar**		**Yelgi**	**Hirebevnur**		
January 2014	1.76	0.99	1.37	0.83	1.75	1.29	0.08 (5.83 %)
April 2014	1.91	1.21	1.56	1.02	0.80	0.91	0.65 (41%)

Irrigation water quality is indicated by electrical conductivity (EC) of water samples measured in mS/cm. As shown in Table 3, EC of river water and bore well water sample was 1.37 mS/cm and 1.29 mS/cm, respectively which were collected on January 2014. The values for April for river and bore well water samples were 1.56 mS/cm and 0.91 mS/cm, respectively. The water samples which were found to have electric conductivity between 0.75 mS/cm and 2.25 mS/cm indicated that water quality was medium for irrigation as per Indian Standards of water quality. The electric conductivity of water samples was higher in river water compared to that in bore well water by 5.83 per cent and 41 per cent during January and April, respectively. The results indicated that first, river water in this condition was less suitable for irrigation compared to bore well water, secondly temporally river water quality was more deteriorated in April compared to January month of the year. Thus, the findings confirm the hypothesis that water in Bhima river was getting polluted and increasing pollution may make the water unfit for irrigation in future.

As indicated in Table 4, average yield difference of sugarcane between polluted and non polluted villages was 3.43 tonnes/ha. The yield difference between polluted and non polluted villages was highest between Chanegaon and Mananklagi followed by that between Shirnal and Halasangi, Dhulkhed and Yelgi, Bhuyar and Hirebevnur. Table 3 also depicts income loss due to pollution. The economic loss ranged from a lowest of ₹ 4,392 in case of Lachyan and Bargudi to highest of ₹ 7,200 in case of Chenegoon and Manankalgi.

As discussed earlier the productivity differentials in sugarcane were decomposed using Cobb-Douglas production function to assess the impact of water quality on crop yields.

However, the difference between the yields could not be attributed to water pollution as the contribution of polluted water to decrease in yield of sugarcane was only 0.88 per cent.

Table 4. Yield and income losses in sugarcane crop

Villages	Yield difference (tonnes/ ha)	Income loss (₹)
Dhulkhed and Yelgi	3.56	6,408
Bhuyar and Hirebevnur	3.38	6,084
Lachyan and Baragudi	2.44	4,392
Shirnal and Halasangi	3.78	6,804
Chanegaon and Mananklagi	4	7,200

The decomposition analysis (Table 5) revealed that yield of sugarcane in water polluted villages was less in non polluted villages. Yield difference due to input uses were 13.10 percent. This implied that there was sub- optimal use of inputs in sugarcane cultivation in polluted villages. However, contribution of water pollution was lower than that of input use. The water pollution depressed the productivity of sugarcane by 0.88 per cent. It can be inferred that use of lower quantities of inputs reduced yield of sugarcane in water polluted villages.

Contribution of inputs to yield reduction in sugarcane was 13.10 per cent. However, increased bullock labour, human labour, organic manure and number of irrigation on sugarcane had positive effect on yields. Negative contributions of other inputs were from plant protection chemicals and seed rate.

Table 5: Decomposition of total difference in productivity of sugarcane crop in polluted and non polluted villages

Sl. No	Source of difference	Percentage contribution
I	Due to polluted water	-0.88
II	Due to difference in input use	
	Seeds	-0.11
	Organic manure	0.67
	Human labour	0.36
	Bullock labour	3.24
	PPC	-0.37
	No. of irrigation	9.31
III	Total due to inputs	13.10
	Total difference in output due to all sources	12.22

Morbidity among the households due to consumption of polluted water was analysed using logistic regression. It can be observed from Table 6 that the variable Vil_c which represents whether the households belonged to polluted or non polluted water was positive and statistically significant at 5 percent level of significance. Those households which belonged to polluted villages were more prone to morbidity either directly or indirectly and showed higher level of morbidity. As per expectation, sign of variables Ow_land was negative, which indicated that mere ownership of land did not mean more exposure to polluted water but they could be employing labourers to work in their fields. On the other hand, landless labourers had higher chances of getting exposed to polluted water as they hired out their labour to work in agricultural fields of others. Edu_head variable was not significant but the negative sign indicated that the head of the household was expected to improve the level of awareness of the family and there was a need for adopting precautionary measures to protect the members from the risks of the polluted water. pvt_toilet was negative but not significant. Pvt_toilet value which indicates the general sanitary and hygienic conditions of the households was also expected to reduce morbidity. Signs of variables Ow_livestock, agri_lab and mig_lab were positive but not statistically significant. Positive sign of Ow_livestock which indicate ownership of livestock means more exposure to polluted water. Positive sign of agri_lab and mig_lab indicated more exposure to polluted water. The results obtained in the present study are in agreement with those reported by Srinivasan and Reddy (2009) but, some variables were significant at higher level of significance.

Table 6: Determinants of morbidity in the study area

	Coefficients	**t-value**
Vil_c	7.528	4.590**
Ow_land	-1.719	-1.036
Ow_livestock	1.789	0.779
Edu_head	-0.062	-0.626
agri_lab	0.11	0.096
family_size	-0.066	-0.623
avg_age	-0.009	-0.153
Fuel	-0.303	-0.267
mig_lab	0.315	0.203
Caste	-1.164	-0.897
pvt_toilet.	-1.354	-0.853
Constant	-1.348	-0.339

** Significant at 5 percent of significance level

Livelihood is a comprehensive concept involving several parameters of activities including capabilities and assets. In this study effect on water pollution on livelihood was assessed in terms of farm incomes, employment and livestock assets. Findings of the study revealed that livelihood of farmers was negatively affected by reduced incomes and employment and increased undesirable expenditure like medical expenses. A few studies have dealt with impact of water pollution on rural livelihoods in the past. Shanthi and Gajendran (2009) studied the impact of water pollution on the socio-economic status of the stakeholders of Ennore Creek, Bay of Bengal (India) and reported that nearly 60 per cent of the sick persons lost less than five working days due to sickness. The average wage lost due to sickness was computed as ₹ 467. Ashraf *et al.* (2010) studied effects of irrigation with polluted water on environment and health of people in, Pakistan and showed that 76.07 per cent of the population was affected by by nail and skin problem and fever and only 23.93 per cent was normal. Abeygunawardane *et al.* (2011) studied socioeconomic implications of water pollution in an urban environment in Sri Lanka. Study revealed that 13 per cent of the families were affected by dengue and chickengunya fever. The total affected individuals were 18 and the mean health cost was ₹ 453 per incident. Adebowale *et al.* (2011) studied effect of industrial water pollution on the livelihood of rural dwellers in Nigeria and showed that individual health of rural dwellers in and around the study area was affected. The ailments included itching of skin (48.2%); miscarriage experienced by females (37.2 %). Pullaiah

(2012) studied Musi river pollution in Hyderabad, India and its impact on health and economic conditions of downstream villages and reported the details of effects of health hazards in terms of number of sick days, number of days of work and average money spent on health hazards which showed that the families were facing problems. Pullaiah (2012a) assessed the economic impact of water pollution of Musi River Hyderabad and study revealed that people were over financial burdened with expenditure on water due to water pollution. Total annual expenditure of the water in the selected villages was ₹ 32, 30,000, this indicated over financial burden on the people in these villages.

Overall economic impact of water pollution is discussed with respect to loss in farm incomes, loss in labour employment, loss in human health and loss in livestock (Table 7). Average loss of income due to loss in yield of sugarcane in polluted village was ₹ 6,178 (57.74 %), income loss due to loss of working days was ₹ 2,175 (20.33 %), loss on medical expenditure was ₹ 1,147 (10.71 %) and loss due to veterinary expenses was ₹ 1,198.67 (11.20%). Total loss to polluted village was ₹ 10,697.93. When compared to non polluted village ₹ 10,697.93 was extra financial burden to the respondents in the polluted villages.

Table 7: Economic impact of water pollution on rural livelihoods

Source	Non polluted villages (₹)	Polluted villages (₹)	Difference	% Difference
Loss on agriculture Income	26,136	32,313.61	6,177.6	23.63
Loss of Employment	5,760	7,935	2,175	37.76
Loss on Human Health	7,050	8,196.66	1,146.66	16.26
Loss on Livestock Health	511.33	1,710	1,198.67	34.42
Total	39,457.33	50,155.27	10,697.93	27.11

Conclusion

Growing multisectoral demand for water while the total potable water supply remaining constant, is putting tremendous pressure on water quality and quantity. This pressure is expected to increase with further growing demand in the future leading to water crisis. In view of these hard facts the present study attempted an economic analysis of impact of water quality on agriculture and rural livelihoods to focus on policy issues. Impact of water quality was assessed in terms of Indian and international standards comparing water samples in the study area. Further, the comparison was made between water samples of Bhima river, which is supposed to be polluted with bore well water samples in the neighboring region with similar agro climatic situations. Several parameters of water quality which included TDS, alkalinity, hardness, BOD, COD, *E. coli*, among others, with standard norms were used for assessing water quality. Most of the parameters were found to have higher values for both river water and bore well water samples. In terms of TDS both river water and bore well water had higher values compared to standards. But, river water was more polluted in terms of total alkalinity total hardiness, BOD, turbidity and bacterial counts both river as well as bore well water had higher values. In case of total alkalinity, total hardness and BOD bore well water had higher values than the river water. As far as turbidity was concerned river water samples had very high values when compared to standard and the values for bore well water. There were inter seasonal differences in the values of these parameters.

Irrigation water quality was tested in terms of electrical conductivity (mS/cm). General standard range for water to be fit for irrigation, at moderate levels, is 0.75 mS/cm to 2.25 mS/cm. Since, the values for both river as well as bore well water samples, across the seasons, were in this range, it could concluded that Bhima river water was less suitable for irrigation especially.

The extent of impact of water pollution on crop yields was studied in terms of yield differences of sugarcane crop (principal crop of the region). in polluted and non polluted villages. On an average there was about 3.43 tonnes / ha yield difference between polluted and non polluted villages. The economic loss ranged from a lowest of ₹ 4,392 in one cluster to highest of ₹ 7,200 in case of another cluster. Decomposition analysis revealed that the difference between yields could not be attributed to water pollution alone as contribution of polluted water to decrease in yield was only 0.88 per cent.

With regard to morbidity among households due to consumption of polluted water results of logistic analysis revealed that villagers belonging to polluted cluster were more prone to morbidity either directly or indirectly.

Overall economic impact of water pollution on agriculture and rural livelihoods was studied in terms of loss in farm income, loss in employment, loss of human and loss of livestock health. It was found that overall livelihood of farmers was negatively impacted by the polluted water. Reduced incomes and employment and increased expenditures on health of human beings and livestock caused a general loss in livelihood status.

Thus, it could be concluded that the impact of consumption of Bhima river water had moderate negative effects on agriculture and rural livelihoods. If unchecked the degree of pollution in the river is expected to rise in the future, therefore following policy measures are suggested to ameliorate the situation.

Policy implications

In view of the findings of the study, following policy measures could be recommended.

1. Since, the water quality tests results in the study were found to be above desirable limits, there is a need for continuous monitoring water quality of the rivers. The Karnataka State Pollution Control Board (KSPCB) has to expand its capabilities to continuously monitor river water quality in the state and laws should be strengthened to punish the guilty.
2. Local government agencies, like muncipalties and Gram Panchayat should undertake regular water auditing for industries, to compile a register of industrial work water treatment.
3. Formulating integrated waste management programme to make sure that industrial waste does not contribute to the contamination of water. In case where such industries are identified as contributor and are permanent adulterator of water, or evading the principle of safe disposal, stringent punitive action should be taken.
4. Local community organizations should be strengthened and trained for social monitoring of surface and ground water bodies on a regular basis. This requires capacity building of community organization, and formation of special task groups and providing logistics and

reporting mechanisms. Amendments to local bodies acts can ensure in corporating these problems.

5. Appropriate ameliorating measures should be initiated to insulate the farm house holds from adverse effects of water pollution on their agriculture and livelihoods.
6. India needs to evolve a sound river policy for protection of its invaluable water resources.
7. Academia and research bodies should focuss on social cost of pollution of water bodies to convince the policy makers.
8. Measures should be taken to arrange meeting to compensate farmers for loss in livelihoods

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