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Research Article

Risk Analysis on the use of Damodar River Water for Drinking Purposes

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Abstract

The paper shows the incorporation of various influencing parameters in water quality. Damodar river is mainly polluted due to mine overburden, fly ash, oil, toxic metals and coal dust, that has been drastically controlled by strict implementation by the Central Pollution Control Board as well as State Pollution Control Board for the effective measures to be taken by the industries and municipal bodies. The study shows the effect of biological parameters like – Biological Oxygen Demand (BOD =Exposure Factor 24.61), Most Probable Number (MPN =Exposure Factor 32.42) and Total Kjeldahl Nitrogen (TKN = Exposure Factor 31) mainly responsible for the river pollution. Similarly, Surrogate Number Level of exposure Factor i.e., SNLF for BOD is 24.61, for MPN is 32.42 and for TKN is 31. The above parameters help in deciding mode of Hazard transmission, Condition, Nature of Risk, Consequences, Severity of Risk as per EF, Severity of Risk as per SNLF, Detectability and Risk Classification. The present study will be helpful for industrialists and environmentalists to analyze the hazard transmission and apply the risk control measures.

Keywords: *Severity of Risk as per EF, Hazard transmission, Risk control measures*

Introduction

An appropriate risk analysis has been done for study of Damodar river water, in Jharkhand (India) for its use as potable water. This river basin is credited of first coal mining in India in 1815 (Singh, 1992). The river is quite wide and carries the effluents of several types like coal mines, coal washeries, coke oven plants, thermal power plants, giant Bokaro steel plant, cement plant and also several big and small townships with different types of potential pollutants, adversely affecting the riverine ecosystem and thus degrading the water quality (Ghosh et al ., 1984; Dhar, 1993 ., Bell and Karr,1993).

Risk analysis on the use of any specific water resources refers to the probability that an event will have a severe effect directly or indirectly on human health and welfare. It is multidisciplinary process, which include the study of the sources, reactions, transport, effect and fate of chemical species in the water and the effect of human activities on these. The risk analysts may travel several times from the same path of multidisciplinary processes for the analysis. It draws on data information and principle of several scientific disciplines like biology, chemistry, physics, medicine, public health, sanitary engineering, geology, epidemiology, statistic, etc. In general the national standard for drinking water is formed from all the above scientific principles to take care of the health and welfare of the consumers. The present study for evaluation of risk analysis has been conducted by consulting several natural water and drinking water standards. The most stringent standards/ norms have been adopted for the study i.e., Canadian, European and BIS 10500. An understanding of the basic concepts of risk analysis is essential for chemists, stack holders and for all others engaged in water science, engineering and management. The main objective is to make aware about the importance of protection conservation and management of our water resources and the immediate action to restrain human activities which lead to water pollution (Savenije and Zaag , 2000; Savenije and Zaag , 2002; Singh et al ., 2013b).

Materials and Methods

The study has been carried out to assess the physicochemical parameters of Damodar river water between Tenughat dam (23°44'06" N and 85°48'36" E) to Panchet dam (23°41'42" N and 86°44'58" E) dam as shown in **Fig. 1,** distributed into seven sampling site. Earlier study have been done by several scientists and researchers on physiochemical parameters of the Damodar river water considering different types of point and nonpoint pollution sources (Tiwary and Dhar,1994; Subramanian, 2004; Singh et al ., 2011a; Singh et al ., 2011b; De, 2010). Many scientists have worked on the factors affecting the mining areas water resources (Choubey, 1991; Tiwary, 2001; Singh, 2012).

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Sampling

The study for identification of risk analysis on the use of Damodar river water has been carried for all the three seasons (pre-monsoon, monsoon and post-monsoon) for one year from 23/5/11 to 13/1/12. Samples for each sampling station were taken at an interval of approximately 7 days for every season. The geographical locations of seven sampling stations covering aerial distance of approximately 100 km of Damodar river are as follows as shown in the **Fig. 1.**

1. Tenughat dam 23°44'06" N and 85°48'36" E
2. Telumochu Bridge 23°42'47" N and 86°12'07" E
3. Upstream of Jamadoba 23°42'48" N and 86°20'48" E
4. Downstream To TISCO 23°41' 30"N and 86°22'42" E
5. Near Sudamdih Railway Bridge 23°39'07" N and 86°26'23" E
6. Near Tasra Water Pumping Station 23°38'28" N and 86°27'54" E
7. Panchet dam 23°41'42" N and 86°44'58" E
8. The distance between the sampling station 1 to 7 is approximately 100 km. The distance between sampling site 1 and 2 is approximately 40 km, between 2 and 3 is approximately 20 km, between 3 and 4 is approximately 6 km, between 4 and 5 is approximately 8 km, between 5 and 6 is approximately 3 km and between 6 and 7 is approximately 30 km.

All most all of the sampling stations falls in the active zone of coal mines of Jharia Coalfield producing prime coking coal along with the allied industries like - coal washeries, active open cast and underground mine, over burden damps, coking coal plants etc. Other huge industries include thermal power plants, cement plants, giant Bokaro steel plant and also densely populated unplanned industrial growth on the both side of the river bank with a large number of point and nonpoint pollution sources. These activities have adverse effect on the river water quality. The sampling station 1 has huge fishing activities. All the stations water was free flowing, clear in appearance, palatable taste and no odour recorded in the sample. Locals complained about the sampling station 7 that during the month of March very offensive smell persists along its surroundings and fishes dies and are visible floating in the dam water. The dissolved oxygen (DO) present in the water samples was deficient with respect to saturation at the sampling temperature as studied.

Water Quality Characterization and Analysis

The physico-Chemical characteristics of sample collected for all the above mentioned three season have been studied by selecting the most practicable methods available in the standard method for examination of water and wastewater as per APHA, 2005; EPA and Water Quality and Treatment, 1971; AWWA (1971).

Methodology

Statistical Interpretation

The risk analysis has been studied based on the water quality with respect to physicochemical parameters variations especially considering biological parameters (Singh et al., 2011b; Singh, et al., 2013a and Singh, et al., 2013b) shown by statistical analysis of the 63 number of water samples of seven sampling stations and their selected 14 physicochemical parameters. The result presented in **Table – 1** highlights the parameters in terms of hazard transmission, condition, nature of risk, severity of risk as EF, severity of risk as SNLF, detectability and risk classification. In the study, for the exceedence factor (EF) and the surrogate number level exposure factor (SNLF), secondary data has been collected (Singh, et al., 2013b).

In the **Table– 1**, Conditions have been evaluated as D (Direct) or R (Routine) contact. Similarly Nature of Risk has been divided into following way – HUL (Highly Unlikely), UL (Unlikely), L (Likely) and VL (Very Likely). Likewise, Detectibility has been classified into four classes – Instantaneous, High, Low and Nil.

Results and Discussion

The above methods of classification of risk analysis for the use of Damodar river as potable water, the parameters having the EF value greater than 10 (Singh et al., 2013b), falls in the critical risk classification and require immediate risk control measures for its use as drinking water. The high value for the parameters like BOD, MPN and TKN are due to manmade activities and decaying of nonorganic matters (NOM) in the river water. They create a potential risk and health hazard on the user. The quantum of risk on the use of river water for drinking purposes has been presented by the self-explanatory **Table-2.** The risk continues mainly due to anthropogenic activities i.e., MPN, BOD and TKN, dissolved geomineral i.e.,Ca, Mg, Na cations and anion i.e., Cl^- , SO_4^{2}, NO_3^-, F^- and total alkalinity. Miscellaneous contributor is Fe (very common as coal mining pollutant) and aggregate property in terms of conductivity. Among the minerals dissolved, iron falls in the moderate category of risk as per European Economic Community Standard (0.05 mg/l) but BIS(1993) IS 10500 limit is 0.3 mg/l. The presence of iron does not show any potential risk on the user.

The risk analysis on the use of the Damodar river water for drinking purposes in terms of consequences and risk control is given in the self-explanatory **Table – 2.** Earlier work done by Singh et al., 2007; Sarkar et al., 2007; Singh, 2013 shows quality evaluation of the river water due to activities like coal mining and associated industries. Risk without treatment of Damodar river water for drinking and domestic purposes cannot be ruled out. The highly organic polluted sampling stations are observed from sampling stations 3 to 5 and then decreases at sampling station 6, showing self-purification capacity of Damodar river water (Singh et al., 2011b). At the sampling station 7, again there is rise in the organic pollutants. Earlier studies shows water contamination from all types of human activities, persistent organic chemicals (POP) and pesticides, toxic metals, common contaminants such as Phosphorus and Nitrogen increasing the photosynthetic activity in surface water and excess coliform and other bacterial population beyond MPN

Table – 1 Physico-Chemical Parameters in Terms of EF and SNLF as Risk Factor

S No.	Water quality parameters	Mode of Hazard Transmission	Conditio n		Nature of Risk	Severity of Risk as per EF	Severity of Risk as per SNLF	Detectabil ity	Risk classification
1	BOD	Ingestion and contact	D	R	VL	24.61	24.61	Low	Critical
2	MPN	Ingestion and contact	D	R	VL	34.42	32.42	Low	Critical
3	TKN	Ingestion and contact	D	R	L	31.00	31.00	Low	Critical
4	Conductivity	Ingestion and contact	D	R	UL	0.717	0.00	Low	Low
5	Cl^-	Ingestion and contact	D	R	L	0.68	0.14	Low	Low
6	SO_4^{2-}	Ingestion and contact	D	R	L	1.32	1.31	Low	Low
7	NO_3^-	Ingestion and contact	D	R	UL	0.327	0.00	Low	Low
8	F^-	Ingestion and contact	D	R	UL	0.951	0.09	Low	Low
9	T Alkalinity	Ingestion and contact	D	R	UL	0.404	0.00	Low	Low
10	Ca	Ingestion and contact	D	R	UL	0.335	0.00	Low	Low
11	Mg	Ingestion and contact	D	R	UL	0.311	0.00	Low	Low
12	Na	Ingestion and contact	D	R	UL	0.931	0.39	Low	Low
13	Fe	Ingestion and contact	D	R	UL	2.48	2.48	Low	Low
14	% DO saturation level	Ingestion and contact	D	R	UL	1.06	0.54	Low	Low

Table – 2 Consequences and Risk Control Measures of Physico-Chemical Parameters

S.No.	**Water quality parameters**	**Consequences**	**Risk control measures**	**Remarks**
1	BOD	Vomiting, carcinogenic, diarrhoea, odour, colour, conjunctivitis	Coagulation, Flocculation, Filtration.	Require immediate action of purification. The user must be informed about the ill effect
2	MPN	Diarrhoea, Dysentery, Cholera and other vector disease	Disinfection (chlorination) UV treatment and ozonation.	Require immediate action of purification. The user must be informed about the ill effect as it may cause cholera, dysentery etc.
3	TKN	Water borne diseases due to rapid growth of bacteria. Nitrates at high concentrations in the body may convert to nitrite, which are toxic salts that disrupt blood oxygen transport	Clarification of raw water, coagulation, flocculation and filtration.	The risk due to TKN is disrupting hemoglobin to methemoglobin conversion. Causes nausea and stomach aches for adults. For young causes blood-oxygen deprivation. Require immediate action of purification.
4	Conductivity	Not perceivable	Do not require.	Water quality is good with respect to dissolve geo-mineral matters.
5	Cl^{--}	Taste, corrosion and palatability are effected.	Do not require.	Does not constitute any adverse remark as they are well within desirable limit of IS 10500 and does not require any treatment.
6	SO_4^{2-}	Gastrointestinal irritation when magnesium and sodium are present.	Do not require.	They are well within desirable limit of IS 10500 and do not require any treatment.
7	NO_3^-	methemoglobinemia takes place.	Do not require.	They are well within desirable limit of IS 10500 and do not require any treatment.
8	F^-	Causes Fluorosis but is well within the essential requirement.	Do not require.	They are well within desirable limit of IS 10500 and do not require any treatment.
9	T Alkalinity	Impart undesirable taste and effect the palatability of water	Do not require.	They are well within desirable limit of IS 10500 and do not require any treatment.
10	Ca	Encrustation in water supply structure and adverse effects on domestic use	Do not require	They are well within desirable limit of IS 10500 and do not require any treatment.
11	Mg	Shows effect as hardness of water	Do not require	They are well within desirable limit of IS 10500 and do not require any treatment.
12	Na	Beyond potable limit it has alarming effect on blood pressure	Do not require	They are well within desirable limit of IS 10500 and do not require any treatment.
13	Fe	Beyond the limit it reduces aesthetic values. It is hepatotoxic and is absorbed on liver, interfere with metabolic process and digestion of food. The excessive amount may cause blood dysentery. It also promotes iron bacteria.	Do not require	They are well within desirable limit of IS
14	% DO saturation level	Lower value of DO may impart unpleasant taste and odour.	Do not require	They are well within desirable limit of IS 10500 and do not require any treatment.

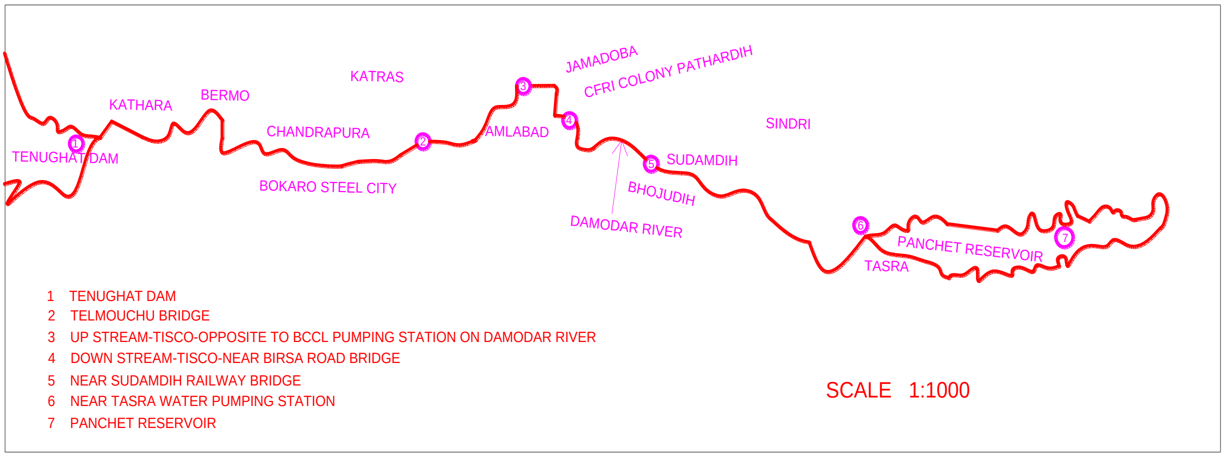

Fig. 1: Map showing seven sampling stations from Tenughat Dam to Panchet Dam

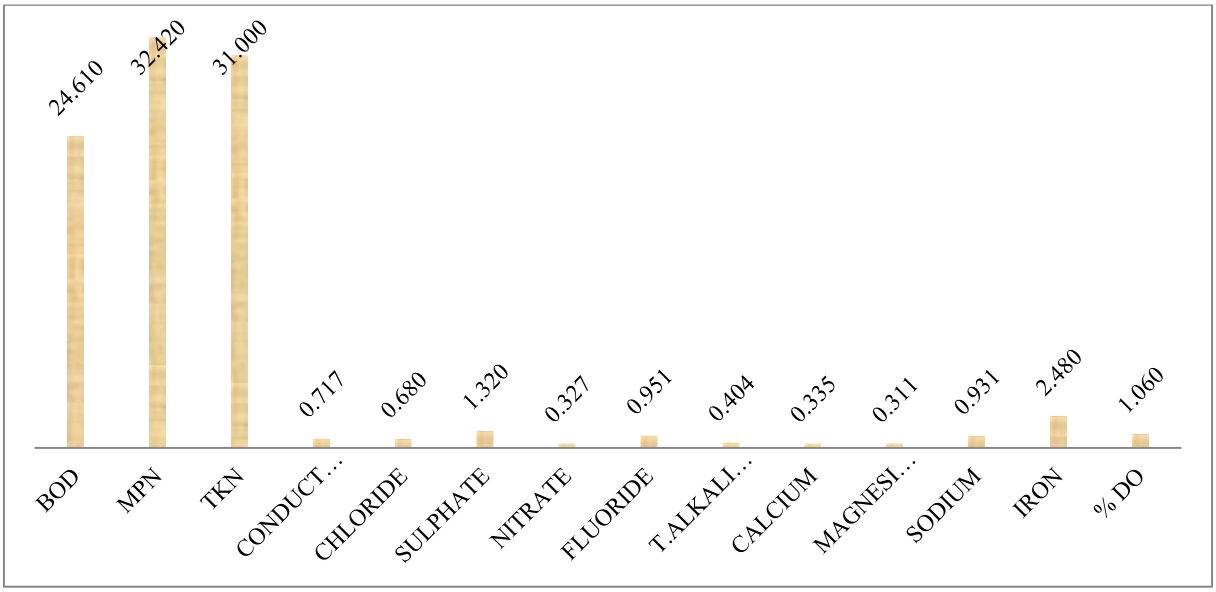

Fig. 2 Graph showing exceedence factor of physicochemical parameters of seven sampling stations

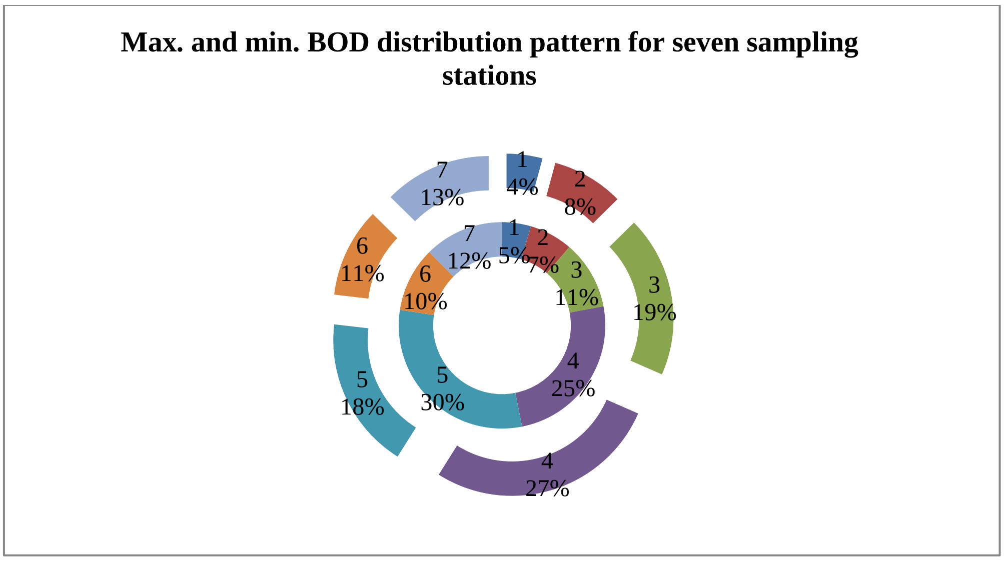

Fig. 3 BOD distribution

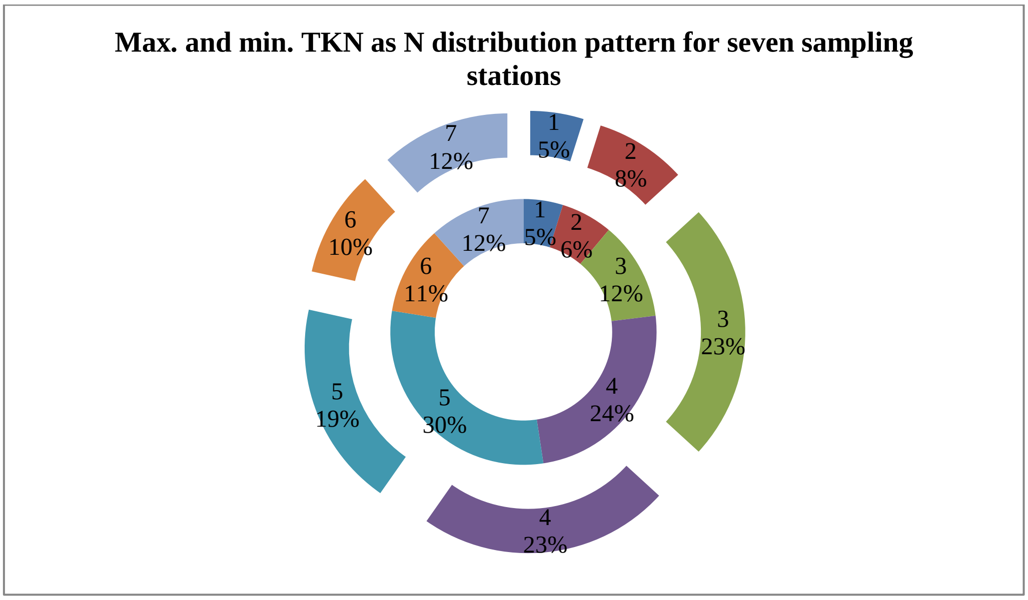

Fig. 4 TKN distribution

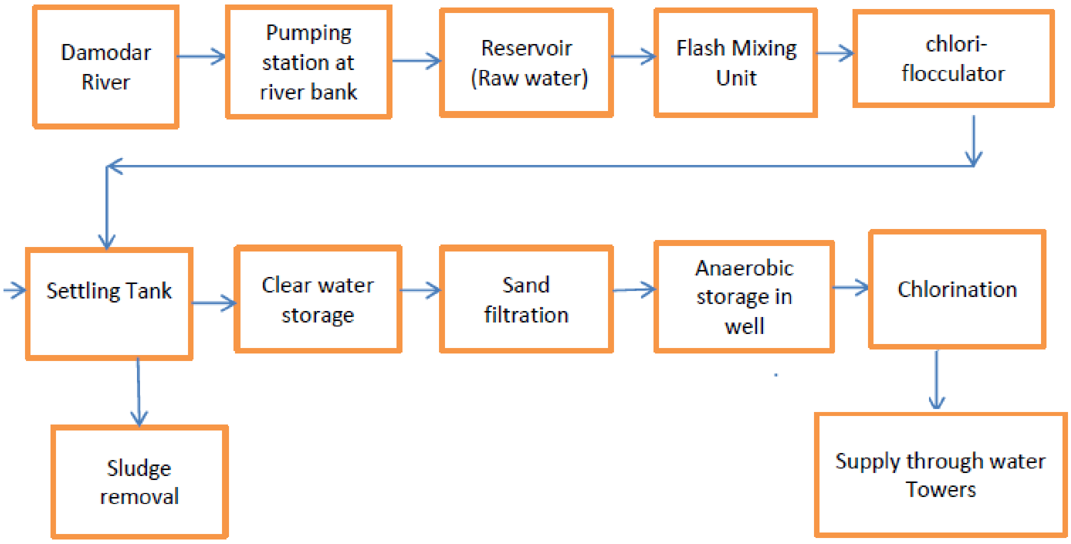

Fig. 5 Flow Chart of water supply from Damodar river to Sindri township

(Most Probable Number) (Subramanian, 2004). The dissolved oxygen in the river water shows the self-purification capacity of the river water and it has been found in adequate concentration to maintain its self-purification capacity. During supply of treated water from water treatment plant to consumers, the probability of contamination of clarifier water with unhygienic water (sewage, stale and contaminated nala water) could not be ruled out and risk on users is an important factor, which can be prevented by maintaining residual free chlorine concentration equivalent to 0.1 ppm at user tap. The higher value of SO_4^{2-} is mainly due to mine water discharge into the river and chloride due to discharge of domestic and sewage. The average urban areas runoff content of Cl^- have been estimated between 3 to 35 mg/L and total Nitrogen is equivalent to 0.3 to 0.75 and from the agricultural runoff the total nitrogen have been estimated between 0.5 to 6.5 (Metcalf & Eddy,2003). Out of the fourteen parameters under study, conductivity, calcium, magnesium, sodium, nitrate and fluoride have been found well below the standard under considerations i.e.,source: Calfornia State Water Pollution Control Board 1952, European Economy Standard as Guideline for safe drinking water and BIS(1993) IS:10500. The major offenders are BOD as shown in **Fig. 3**, TKN as shown in **Fig. 4** and MPN are of great concern for their removal to make the river water as potable water. Moderately polluted rivers generally have a BOD value in the range of 2 to 8 mg/L. Municipal sewage which is efficiently treated by a three stage process would have a value of about 20 mg/L or less. In the complete study of river stretch shows BOD, TKN and MPN, higher values at sampling stations 3 to 5 and also at sampling station 7, according to secondary data from Singh et al., 2011b. A brief of the control measures adopted in sindri township (Jharkhand, India) **Fig. 6** water supply from Damodar river, may be presented through the

Fig. 6 Location of Sindri township along Damodar river

flow sheet/ Block diagram as shown in **Fig. 5.**

The risk analysis of the river water is one of the prime components in terms of the environment and requires an integrated effort to solve the alarming problems of potential organic pollutants. This effort may include expertise from all branches like chemical, physical, biological, microbiological, social and economic field, so that the quality of water resources may be upgraded and all the users in the region can avail potable quality river water, free of cost.

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