Identifying Anthropogenic Factors of Groundwater Pollution through Student's Opinion in Rural West Bengal

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Abstract: Increasing knowledge about important factors of groundwater pollution caused by anthropogenic activities i.e. human actions demands an understanding of the reality. Methodology: Hence, in this study, the researchers used factor analysis or principal component analysis to identify significant anthropogenic factors affecting the groundwater quality in two districts of West Bengal. Survey was employed to gather primary data from the school students of the two districts. Cluster sampling method was used to identify the sample for the study. The factors identified in the research were an outcome of the perception of students having exposure to environmental education including field projects and live experience in rural areas. The four factors were identified after data analysis: Human-Collective-Induced environmental Pollution, government Negligence including Non-Eco friendly Agricultural Policy, non-Eco Friendly daily human activities and non-Environmental Friendly Sanitation arrangements by Local Bodies. This study indicates the importance of positive intervention to reduce anthropogenic causes, at individual, community and government level. The study hints obliquely at lack of information and knowledge based positive practices in the area where the study took place. This problem is suggested to be redressed through communication intervention.

Keywords: Groundwater Pollution, Human-Collective-Induced Environmental Pollution, Principal Component Analysis.

1- Introduction

We coexist on a planet where fresh water is meager 2.5% of the total water and 30.1% of fresh water is groundwater. It shows how small our freshwater reserves are considering the world populations enormous drinking and cooking water needs. Implied in

the situation is the importance of keeping this reservoir unpolluted. Several researchers argued that increased environmental knowledge prompts a change in human behavior towards the environment and helps keep pollution in check (Abrahamse and Matthies 2012; Levy and Maranas, 2012). Water is vital element for human being and due to anthropogenic activities; its health for drinking is threatened (Ravan Nakhjavani and Fataei, 2015). Groundwater depletion and contamination due to water-intensive agriculture and industrial activities have become a threat to sustainable living; attest huge number of studies (Simeonov et al. 2003, Mokaya et al. 2004; Azrina et al. 2006; Wang et.al. 2007; Hai et al. 2009; Rashid and Ramshoo, 2013).

Many human health hazards such as arsenic poisoning and crop poisoning in agriculture are taking serious proportions. Despite definitive knowledge about the gravity of such dangers, and government policies to halt the deterioration, the situation is not encouraging. Groundwater depletion caused by human activities further makes soil loose adhesion and cohesion properties, thus leading to land submersion in the long run (Chitsazan et al. 2019; Li, Z., Yang et al. 2019). Some argued that communication plays a major role in improving environmental knowledge (Hage, 2010; Bouma, 2019) which helps mitigating groundwater pollution. Increasing knowledge about important factors of groundwater pollution caused due to anthropogenic activities i.e. human actions demands an understanding of the reality.

Pollution authorities develop models and strategies to combat environmental pollutants. The much more traditional approach relies on the emission inventories to access and monitor the flow of pollutants and its levels of concentration. However, Receptor models use the observation method to combat the same problem and are called "receptors". In studies such as these, there are several models to choose from. The most widely used ones are Factor Analysis (F.A), Chemical Mass Imbalance (CMB), and Enrichment Factor (EF). The objective of this study is to identify the anthropogenic factors of groundwater pollution through students' knowledge, attitude and performance in West Bengal. In this study, the researchers used factor analysis or principal component analysis to identify significant anthropogenic factors affecting the groundwater quality. The factors identified in the research shall help to create the micro-environmental perspective of groundwater pollution.

2- Materials and methods

Belkhiri (Belkhiri et al. 2011) in his paper 'A multivariate statistical analysis of groundwater chemistry data.' used the multivariate statistical analysis together with principal component factor analysis to differentiate among the possible multiple sources of groundwater pollution and its reason of contamination. The study partially dealt with the anthropogenic elements and focused more on the chemical factors of contamination.

Aiuppa (Aiuppa et al. 2002) researched the quality of groundwater found in Mount Etna with over 276 groundwater samples. The key findings of the research were mainly contamination from agriculture, urban waste, leaching of host basalt, geological events such as rising sedimentary saline brines from the base of the mountain). In recent decades, climate change, dam constructions, unsustainable industrial development and excess exploitation of groundwater for agriculture have been the main cause of drying of Lake Urmia.(Valiallahi, et al.,2019).In this paper multivariate statistical analysis method was employed to find out the factors responsible for groundwater pollution. However, the research also indicates that two of the three factors which are natural in occurrence have the potential of adding much-needed minerals into the groundwater reservoir below Mount Etna; it shall benefit the health and livelihood of the community living in and around Etna. This research is key to understanding why we need

to focus on the anthropogenic factors because they cause more harm than we can imagine.

Huang (Huang et al. 2013) studied the changes and effects of rapid rural industrialization of Dongguan region of China, The main highlights of his research focus on human activities which have resulted in the contamination of groundwater due to rapid industrialization. He identified the anthropogenic causes with principal component analysis or factor analysis and hierarchical cluster analysis. Four factors were identified like sea water mixing as contamination, water-rock interaction and acidic precipitation, heavy metal pollution which is a result of human activities such as industrialization, agricultural pollution and sewage intrusions with the groundwater clusters found in the area. It is much more evident from the research that out of the four factors the major factor revolves around human activities

Another study from the Yunnan province of China believes that groundwater plays a major role in the socio-economic development in the community. Due to the rapid increase in population, the groundwater levels become insufficient for human consumption. Increasing agricultural land affect groundwater levels at the chemical level. Jiang (Jiang et al. 2009) focused on the Nandong Underground River System (NURS) to study the water quality of the area. The researcher gave definitive proof of a change in chemical composition due to the anthropogenic effects of groundwater. The study was conducted by R-mode factor analysis which revealed factors such as human activities like agricultural land use, use of fertilizers, and water-rock interaction (dolomite and limestone). The research still weighs human activities as the major source and normal geological events as a minor effect on groundwater contamination.

Khatri and Tyagi (Khatri and Tyagi, 2014) added a general overview of the problem that is being discussed in this research. The researcher added that apart from natural causes such as weathering rocks, evaporation, wind patterns, soil leaching, run-off due to hydrological factors, the anthropogenic factors pose a more intense threat to groundwater pollution, the research findings include agricultural land use, ineffective use of fertilizers, animal husbandry, deforestation, untreated sewage, mining, and recreational activities. The researcher also opined that due to contamination of groundwater there has been serious damage to ecology and environment of the particular rural and urban community.

Besides studies focusing on the groundwater of the continental plains, mountain base, rural and urban areas as discussed above, there are studies on groundwater of other geographical terrains. Kura (Kura et al. 2014) focused on the groundwater pollution of a tropical island. DRASTIC and GALDIT[3] models were used to measure the vulnerability of groundwater due to an anthropogenic cause. Both models give definitive proof of anthropogenic causes and seawater intrusion as one of the major causes of groundwater contamination as validated by Pearson's correlation matrix. Masetti (Masetti et al. 2008) employed a very different measurement technique called the weights of evidence modeling technique to help analyze the natural and anthropogenic causes of groundwater pollution. The research was conducted at the Po Plain (Northern Italy). Well water was analyzed. The results gave a negative and positive association with geo-environmental and nitrate content in groundwater. According to the research, the nitrate content influx was due to anthropogenic causes within the community.

The literature review in preceding paragraphs offers an idea about different human interventions as causes of

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[3] DRASTIC & GALDIT system is the widest method used to evaluate intrinsic vulnerability for a wide range of potential contaminants.

groundwater pollution. However, the above studies are more into analyzing chemical aspects of groundwater looking into pollution as a harmful change in the chemical composition of groundwater. While the literature review gives us a fair idea about different causes of groundwater pollution, these do not offer us a perception of people about such danger. The current research, on the other hand, tries to understand student's opinion about groundwater pollution and the role of human beings. Because most of the previous research is limited to one side of the fact of chemical change in water composition due to human induced activities, this study tries to focus on the fact of human understanding about how much they affect the groundwater, not by calculating the contamination found in the groundwater rather from a more social science approach. Hence, it was important to mention the previous studies which focus on the former.

In this research, the researchers are trying to identify the anthropogenic factors employing the principal component factor analysis to identify the primary human factors which influence chemical change in groundwater pollution. The factor analysis helps to identify the principal components called factors affecting the problem in question. The researchers did a quantitative study to understand and explain the factors responsible for the anthropogenic groundwater pollution. The researchers employed the survey of statement method; as given in table 1 below (Factor Analysis Result) to identify the anthropogenic factors responsible for groundwater pollution. This research does not question how or why it just states the facts through empirical shreds of evidence.

Respondents in this research are from two districts of West Bengal, namely Hooghly and Burdwan, where rural areas face groundwater scarcity for agriculture and day to day use. Over the last few years, the uses of submersibles have increased in the area drastically despite routine awareness efforts. Students from high school to Postgraduate level who had studied

environmental science as a part of their school or college curriculum were taken as respondents. The student population was considered as respondents for two reasons, to understand how far environmental education creates an informed future generation and how concerned the students are about the bleak future due to the groundwater problem.

2-1- Sampling and Analysis Method

The study was conducted for (n=190) respondents. The respondents were all (12<23) years of age living in a similar semi-urban area. Of which 20% were Post Graduate students, 60% Under Graduate students and 20% High School Students.

Table 1: Student Demography

Students	No of Respondents		Age
	Male	Female	
High School	20	18	14-16
Undergraduate	74	70	17-20
Post Graduate	23	15	21 and above

The primary study was survey-based and was conducted in the districts of Burdwan and Hooghly (West Bengal, India) (Fig.1).

Fig. 1: Districts of Burdwan and Hooghly (West Bengal, India)

The researchers employed a cluster sampling method to carry out the survey; the cluster sampling method was used to serve the purpose of the study, which is about students and their viewpoint in

understanding the anthropogenic factors. The sampling formula used to determine the cluster sample size is as follows:

$$SS = \frac{Z^{2*}(p)^{*}(1-p)}{c^{2}}$$

Where:
Z = Z value (e.g. 1.96 for 95% confidence level)
p = percentage picking a choice expressed as a decimal (.5 used for sample size needed)
c = confidence interval, expressed as decimal (e.g., .04 = ±4)

The student population, according to the Confederation of Indian Industry (CII) as of 2016 was 19 lakh enrollments in schools and colleges of Hooghly and Burdwan district combined. Therefore, the sample size was considered as (n=190) respondents with 95% confidence level and 7.1 confidence interval.

Factor analysis (FA) was used for statistically understanding of significant data sets. Factor analysis (FA) is a method of analysis in which the estimations of observed data are expressed as elements of various conceivable causes with a specific end goal to discover what most important (Brown, 2015) is. The researchers used (n=15) statements to conduct the study with a 5 point Likert scale. The scale here is used to understand the people's attitude towards the topic, which helps us to identify the factors from the students perspective. The basis of this research lies in understanding the students' opinion on groundwater pollution. The 5 point scale used in this research ranges from Completely Disagree, Disagree, Neutral, Agree, and Completely Agree.

Table 2: Statements

Sl.No	Statements
1	I think there is a relationship between running water pollution from rivers and groundwater pollution.
2	I think urban wastes are creating pollution in neighboring villages
3	I think digging wells very deep causes more groundwater pollution.
4	Health problems will increase with increase in pollution
5	I think industries are responsible for poor groundwater quality
6	I think Chemical Pesticides pollutes groundwater
7	I think excessive agricultural use of land pollutes groundwater
8	The government's water treatment plants do not provide safe water for drinking
9	I feel the local government has no restriction on submersible well installation.
10	I feel that shortage of rain lowers the level of groundwater and we are responsible for that.
11	I believe that Hand pumps are the answer to water shortage
12	I am not likely to harvest rainwater for daily use.
13	I am not likely to reuse groundwater for daily use.
14	I feel the bad sewage system in my village leads to diseases.
15	I believe that doing the toilet outside pollutes the water

The statements were of two types – first type for knowing students understanding of reasons behind groundwater pollution; the second type to understand their apprehension of bad effects of groundwater pollution. To arrive at 15 statements (Table 1), a battery of 30 statements was prepared through the literature review mentioned above and discussion with groundwater pollution experts.

2-2- Findings

2-2-1- Principal Component Factor Analysis: First a set of principal component analysis was done and reliability test of the statement set was performed. Table 1 represents the factor analysis table where we have found (n=4) factors with Eigen Value (>1). The four factors and variables are hence divided accordingly based on the factor loadings as given in the table 4.

2-2-2 The Factors identified:

2-2-2-1- Factor 1: Human-Induced environmental Pollution (α=.914): some research proves that human-induced environmental pollution causes a lot of damage to our environment (Ferrari and Harris, 2011; Tuomainen and Candolin, 2011). The factor explains the ways in which humans pollute the surface environment and how this pollution affects the groundwater, for example, the use of chemical pesticides, polluted running water, and industrial effluent. Our finding confirms Sophocleous's findings (Sophocleous, 2002[a]; Sophocleous, 2002[b]) about the factor of human-induced groundwater pollution which is the first factor in our research with the highest Eigenvalue (7.837) and

variance explained (52.246%). This constitutes more than half portion of the total 100% variance. We can interpret that this is the most important factor and helps prove the objective as mentioned in the research.

2-2-2-2- Factor 2: Government Negligence including Non-Eco friendly Agricultural Policy (α=.874): The factor explains how the groundwater quality deteriorates due to inappropriate policy-making and implementation. The Centre for Study of Developing Society (CSDS, 2015) submitted a report on Indian condition of farmers and the agricultural policy which states that villagers are not benefited from the policies even if they are aware of it. It is already stated in our paper that environmental knowledge is very

Table 3: Ground Water Levels

State	Gross annual replenishable groundwater resource (BCM/year)	Net annual GW availability (BCM/year)	Annual GW draft (BCM/year)	Level of groundwater development (%)	Gross replenishable GW per unit of NCA (MCM/'000 ha)
West Bengal	30.36	27.46	11.65	42	5.55

Source: Central Groundwater Board (data downloaded from website www.cgwb.in on 1st June 2019) .

For solving environmental problems. It comes to the fact that if villagers are unaware of the policies that the government provide, then it is difficult for the farmers to act according to wishes of the government and the policies provided by them. A newspaper report by Rohsan Kishore mentions (Kishore, 2018) that high export demands on rice from West Bengal are directly affecting the groundwater levels because rice cultivation is water-intensive cultivation. The government is not looking towards more sustainable options as an alternative to the water-intensive agriculture technique. The area studied in the research is mainly agricultural land with rice cultivation being the primary crop year round. The responses gathered from students of two rice essential cultivating districts of West Bengal namely Hooghly and Burdwan

substantiates that there are government negligence and lack of sustainable policies to support pro-environmental human activities. Here groundwater is extracted by wells, hand pumps and submersibles- the three methods commonly used in Asia and Africa. Excessive use of submersibles causes threat to arsenic poisoning because arsenic is found in groundwater which enters the ground water naturally or from industrial activities (Upadhyay et al. 2019) other contaminants like aluminium, antimony, barium, beryllium, cadmium etc (USGS). A report published by Times of India on Oct 7th, 2018 states the situation of groundwater contamination in West Bengal. The groundwater bill and act 2005 restricts overusing of submersibles but still, the situation has not improved since (Sengupta, 2011). In table 1.1 we can see that the

annual availability and draft is very low below 30. And replenishment is 5.5 with very little scope of getting replenished with the level of water in West Bengal.

The factor the researchers are discussing is about the non-eco-friendly agricultural policy, the excessive installation of submersible pumps with gradually increasing depth of pipes (as water level goes down) to extract groundwater for irrigation can be sighted as a major non-environmental-friendly policy in West Bengal. Some research like (Brusseau and Maier, 2004; Campbell, 2009) believes that submersible and hand pump if used scientifically can solve the problem of groundwater pollution. Hence, it can be believed that effective utilization of the information in hand with proper communication can help in mitigating the problem of groundwater pollution.

2-2-2-3- Factor 3: Non-Eco Friendly daily human activities (α=.884): Human activities like washing clothes on running and freshwater, throwing plastics and other waste materials, defecation near water bodies etc. contaminates the groundwater as it seeps underground. Researchers studied human-induced groundwater pollution from the collective activities earlier but this factor, looked into from the response of students highlight the problem from individual human day to day activities that affect the groundwater to the chemical level. Earlier Ahmad (Ahmad, 2015) found that over-excessive utilization of the natural resources that include groundwater contamination as humans use water for their daily use. Two other earlier researches related to the factor in discussion (Royne et al. 2011; Mishra; 2017) state that over-excessive utilization of the resources creates health issues which affect the socio-economic condition of the people adversely. Human consumption and management of water in day to day activities put a lot of pressure on the groundwater and in turn affects the lives of the people in varying ways.

2-2-2-4- Factor 4: Non-Environmental Friendly Sanitation arrangements by Local Bodies (α=.839):

Autonomous local self-governing bodies such as municipalities, city municipal corporations, and gram panchayets are having responsibility to implement sanitation schemes and proper drainage in their localities and make people change their behavior towards healthy sanitation and hygiene practices. However earlier researchers found that non-environmental friendly sanitation arrangements by local bodies lead to sanitation practices that pollutes groundwater. Uddin (Uddin et al. 2014) stated in their research that improper sanitation is a threat to water supply in general while specific studies over a long period of time (Stenström, 2004; Kumarasinghe et al. 2013) linked improper sanitation to groundwater pollution in their studies. In our study from perception of students having exposure to environmental education including field projects and lived experience in rural areas, we find the factor with Eigenvalue (1.088) and variance explained (7.253%) to be significant to the study.

2-2-3- Validity and Reliability

The validity and reliability of the findings as investigated by the researcher is understood by the variance explained by each and every factor. For factor 1, which is the most important finding of this research it is 52% and the rest accumulates to around 80% of the total variance explained by the factors identified from the study. Only 20% variability of the data is still unexplained which constitutes other factors that was removed from the study because their Eigen value was not greater than 1. The sample size confidence level was set at 95% hence, we can say that the data findings has a confidence level of 95% to be precise with 7.1 interval ratio as mentioned in the methodology portion of the study. The primary statements used for the study generated out of the literature review which validates the statements used for the study.

Eigenvalue (greater than 1) denoting significance of the statements included in these factors. The four

Table 4: Factor Analysis Result

Factor	Eigen Value (>1)	% of Variance Explained	Cronbach's Alpha (>0.5)	Variables	Factor Loading (>0.6)
F_1: **Human-Collective Induced Environmental Pollution**	7.837	52.246%	.914	I think there is a relationship between running water pollution from rivers and groundwater pollution.	.857
				I think urban wastes are creating pollution in neighboring villages	.852
				I think digging wells very deep causes more groundwater pollution.	.830
				Health problems will increase with increase in pollution	.729
				I think industries are responsible for poor groundwater quality	.603
F_2: **Government Negligence including Non-Eco friendly Agricultural Policy**	1.173	11.421%	.874	I think Chemical Pesticides pollutes groundwater	.884
				I think excessive agricultural use of land pollutes groundwater	.764
				The government's water treatment plants do not provide safe water for drinking	.665
				I feel the local government has no restriction on submersible well installation.	.686
F3: **Non-Eco Friendly Daily Human Activities**	1.391	9.271%	.884	I feel that shortage of rain lowers the level of groundwater and we are responsible for that.	.774
				I believe that Hand pumps are the answer to water shortage	.856
				I am not likely to harvest rainwater for daily use.	.670
				I am not likely to reuse groundwater for daily use.	.620
F4: **Non-eco-friendly sanitation arrangements by local bodies.**	1.088	7.253	.839	I feel the bad sewage system in my village leads to diseases.	.731
				I believe that doing the toilet outside pollutes the water	.794

4- Conclusions

The data from perception of students identifies four factors having Cronbach's alpha value (more than 0.5) showing significance of the factors along with factors that were identified in the research align with the research objective.

Factor 1- Human-Induced environmental Pollution

Factor 2- Government Negligence including Non-Eco friendly Agricultural Policy

Factor 3- Non-Eco Friendly daily human activities

Factor 4- Non-Environmental Friendly Sanitation arrangements by Local Bodies

We can identify the human induced factors which affect groundwater pollution according to the students' perception. The methods used in the research include cluster sampling based survey research employed with factor analysis method. Therefore this study indicates the importance of positive intervention to reduce anthropogenic causes at ground level i.e. individual and community level besides government policy change and implementation. The study hints obliquely at lack of information and knowledge based positive practices in the area where the study was taken up. This problem is suggested to be redressed through communication intervention.

Acknowledgement:

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