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A study on various approaches for identification of sources of ground water contamination: An Indian context

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Abstract — *Ground water contamination is always an unfavorable incident of the surrounding largely because of potential manmade actions, physical and chemical constitution, rapid industrialization, acidification, waste disposal, road accidents, nitrate, and uncontrolled use of pesticides, mine wastewater and insufficient care taken in sewage disposals. The source of contamination identifying technique requires systematic planning and appropriate selection method looking to the objectives. In recent past, GIS-based geostatistical modeling, multivariate statistical analyses, Artificial Neural Networks and surface geophysical techniques have been used to identify the sources of pollution across the India using basic geology and hydrogeology of the location and type of specific contaminant of affected area. Literature study states that Cr, Mn, Fe, Co, Ni, Zn, As, Sr, Ba, and Pb were the major heavy metal along with physical and chemical pollution parameters monitored on sampling points from a hydro geochemical survey on surface and groundwater of industrial area of country. In India, the industrial area of central and southern Gujarat, Rajasthan, Tamlinadu, Andhra Pradesh, Chennai and Mumbai were leading state noticed with metal pollution in water and soil. This review study focused on the significant research work of identification of various sources of ground water contamination in different states of India.*

Keywords- *Ground water, PHEs, metal pollution, geostatistical modeling, geophysical technique, ANN.*

I.INTRODUCTION

The Ground water is an economic resource for public and irrigation water use and so it's necessary to address the issue of its contamination. In order to prevent future ground water quality problem, accurate identification of contamination sources in spatial extent has an utmost priority for decision making in the direction of action. When man-made products like gasoline, oil and chemicals get into the ground water table and cause it to become unsafe for use, the ground water gets contaminated. The major courses are rapid industrialization, waste disposal, uncontrolled use of pesticides, mine wastewater and insufficient care taken in sewage disposals, etc have played a major role for its pollution.

Literature states, more than 85% of the public water supplies are obtained from wells. The industrial waste water and agricultural water leads to heavy metal contamination which later percolates to ground water table. The monitoring of heavy metals like Cr, Mn, Fe, Ni, Zn, As, and Pb along with physical and chemical pollution parameters on sampling points and for geochemical data collection requires systematic planning and appropriate method.

However, due to several constraints, the research study of source identification of ground water contamination across the India is very less and required to marginally explore.

II.VARIOUS APPROACHES FOR IDENTIFICATION OF SOURCES OF CONTAMINATION

In last 2-3 decades, the awareness in the direction of detection of ground water contamination is increased across the globe. However, still this field has a greater scope to explore and innovation though it may expensive up to certain extent. There are various approaches for identification of sources of contamination in ground water reviewed in the present study mainly based on statistical analysis for multiple pollution parameters as geochemical data. For the objective of source location of pollution, different approaches were proposed viz, GIS based geostatistical modeling and multivariate statistical analyses with PCA and HCA (Deepesh Machiwal and Madan K. Jha 2015), Artificial Neural Network (Raj Mohan Singh et al., 2004), ANN based simulation-optimization model (Sophia Leichombam, 2016), Data parsimonious model (Jyoti Chaubey and Deepak Kashyap 2017), Linked optimization –simulation approach and Nonlinear Optimization Model (Bithin data et al., 2009; Pooran s. Mahar et al.2000), Multivariate statistical analyses with PCA, CA and CM components (T.S.R Umamageswari et al., 2016; Shiv Shankar et al., 2014) and Office And Field Identification Of Sources method by a methodological guide of 'Ground water Contamination Inventory'(Alexander Zaprozec, Co-ordinator and Editor of Project Working Group of IHP-V, 2002). All these various approaches have been

critically reviewed based on actual work done. In addition, the literature states that outside country of India, there are some significant works with various other approaches are observed for the detection of sources of ground water contamination. The statistical method with land use analysis, Non negative matrix factorization combined with custom made semi supervised clustering algorithm technique, Simulation modeling using MODFLOW and MT3DMS model, Hybrid optimization techniques, Chemical and isotopic analyses and Descriptive statistics method are having some potential scope of application at suitable conditions.

III.OVERVIEW OF SOURCE IDENTIFYING TECHNIQUES

This study focuses on the various techniques to identify the sources of contamination in ground water. Particular method or model can be selected based on available variable of pollution parameters and probable sources of object in the vicinity of study area. The techniques observed in major state of India for identification of source location of pollution are GIS-based geostatistical modeling, Multivariate statistical analyses and Office and field identification of sources. Now here, few largely used and significant methods are mentioned among the available literature.

3.1 GIS-BASED GEOSTATISTICAL MODELING

For source identification of pollution parameter can be utilized significantly by with GIS environment. The Geostatistical modeling provides underlying factors which can control hydro geological process. The kriging modeling (one of the geostatistical modeling) is useful for analyzing hydro-chemical data at a regional scale. To estimate spatial distribution of the significant Principle Component (PC) or factor score for the contamination period in years (say 10 to 15 years), GIS-based geostatistical modeling approach can be adopted by following three steps.

1st step: Semi variance structure of factor scores can be obtained by experimental semivariogram. (Deepesh Machiwal et al., 2015). Experimental semivariogram is on the outcome of geostatistical modeling.

2nd step: Most-widely used geostatistical models are viz. Spherical, Exponential, Circular and Gaussian were fitted to experimental semivariogram of the significant factor score separately for those years by choosing appropriate model parameters.

3rd step: The best-fit geostatistical model was selected based on three goodness-of-fit criteria, i.e. root mean squared error (RMSE), correlation coefficient(r) and coefficient of determination (r^2). After selected best fit model among above, it can be used in GIS environment to determine spatial distribution. This spatial distribution of geochemical data can be interpreted for source identification.

3.2 MULTIVARIATE STATISTICAL ANALYSES

The multivariate statistical technique is a valuable tool for the evaluation of spatio-temporal variations and interpretation of complex water quality datasets, apportionment of pollution sources/factors (natural or anthropogenic). Groundwater samples can be taken from various bore well locations. These bore well data can be interpreted using multivariate statistical analytical approach which consists of principal component analysis, clustering analysis, and correlation analysis (Ashish et al., 2014). The result obtained from such analysis gives pollution parameters and its sources. This approach is discussed below.

Cluster Analysis

The Cluster Analysis (CA) can be applied to group the groundwater sampling locations, so that the sample location of similar cluster with respect to ground water quality can be differ from other clusters. This classification helps in identifying group of the location according to sources of specific groundwater contamination. The CA is an unsupervised pattern recognition technique that uncovers intrinsic structure or underlying behavior of a dataset without making a priori assumption about the data, in order to classify the objects of the system into clusters based on their similarities (Deepesh Machiwal et al., 2015).There are two major categories of CA is hierarchical and non-hierarchical. Hierarchical cluster analysis (HCA) is the most common approach in which clusters are formed sequentially, starting with the most similar pair of objects and forming higher clusters step by step. This process consists forming and joining clusters is repeated until a single cluster containing all the samples is obtained. Results can be displayed as a tree diagram (or dendrogram), which provides a visual summary of the clustering process by presenting a picture of the groups and their proximity with a dramatic reduction in dimensionality of original data. The tree diagram is considered as the better method for displaying HCA results (Deepesh Machiwal et al., 2015; Kruskal and Landwehr, 1983).

Principal Component Analysis.

Principal component analysis (PCA) commonly used statistical methods for the critical analysis of groundwater contamination. PCA is used to reduce multidimensional datasets to lower dimensions for analysis of ground water pollution. PCA can be applied to reduce the analytical data of each sampling site, which can be correlated to a smaller set

of interpretable principal components. The PCA can be utilizing to create a new group of groundwater variables from the previous dataset.

Correlation Analysis/Matrix (CM)
A correlation matrix (CM) can be attributed used to identify the relationship between the various pollution parameters and their sources.

3.3 ARTIFICIAL NEURAL NETWORKS

Artificial neural networks are highly sophisticated paradigms that borrow features from human and animal brains that enable recognition of patterns within data. The ANN learns to solve a problem by developing a memory capable of associating a large number of input patterns with a resulting set of outputs or effects (Raj Mohan Singh et al., 2004).
The Artificial neural networks can recognize a relationship between the variables from particular pattern which can be useful to unravel complex problems like nonlinear modeling, classification, association and its control. ANN is potentially useful for approximating the cause and effect relationships in a complex groundwater system. The method is characterizing unknown pollution sources using artificial neural networks. Data for training the ANNs are using a numerical groundwater flow and contaminant transport simulation model. A typical conservative pollutant is considered. This trained network is then utilized for the identification of pollution sources for specified concentration observation data at given locations (Raj Mohan Singh et al., 2004).

3.4 OFFICE AND FIELD IDENTIFICATION OF SOURCES

The identification of contamination sources means to find and locate them, and is necessary for all kinds of inventories regardless of their purpose and scope. The method for this purpose is outlined as below.

Office identification of sources
The first phase of the source identification process is largely an office (file) study. Much of the information on contamination sources probably may already be available, but in scattered locations. Availability of data sources will depend on the legal and institutional framework, dependence on groundwater for water supply, degree of development, tradition, etc. The quantity Sequence of methods used for source identification and quality of available information as well as the accessibility to this information may vary substantially (A. Zaporozec et al. 2014).

Custodians of information on existing contamination sources
A substantial amount of information on existing contamination sources may be found in the form of routine records or documents recorded or assembled in the day-to-day operations of agencies at various levels of government (local, regional, state, provincial, or national).

Custodians of information on potential sources of contamination
Potential data sources and their custodians for the following contamination sources like agricultural and forestry practices, urbanization, mining, industrial activities and transportation.

Spatial extent of existing groundwater contamination
The extent of existing groundwater contamination should be clarified especially around the suspected natural and anthropogenic sources of contamination or in heavily industrialized areas.

Field identification of sources
The need of additional information should be carefully assessed and additional means of obtaining this information selected These additional steps in the inventory process will help identify information on sources that were unknown due to oversight, lack of regulatory controls, or lack of concern. Collecting information on unknown sources generally requires some type of direct contact with landowners as they are likely to be the only ones who know about a source. This contact can be in the form of personal interviews or surveys (mail, phone, or door-to-door). (A. Zaporozec et al. 2014)

3.5 NON LINEAR OPTIMIZATION MODEL

Nonlinear optimization model can be used for estimating unknown magnitude, location and duration of groundwater pollution sources under transient flow and transport conditions, also it incorporates the governing equations of flow and solute transport as binding equality constraints and thus it essentially simulates the physical processes of transient flow and transient transport in the groundwater systems (Pooran s. Mahar and Bithin datta, 2000).

This model identifies unknown sources of pollution by using measured values of pollutant concentration at selected locations. Performance of the proposed model is evaluated for an illustrative study area in a hypothetical confined aquifer

under different cases of data of ground water pollution. The objective of the model is to find the best possible match between the observed and model estimated concentrations at selected sampling station and time.
The identified direction in the nonlinear optimization model links the groundwater flow transport simulator and the optimization method (Bithin data et al., 2009).

IV. DATA REQUIREMENT

The present study reviews the various approach for the identification of sources of ground water contamination across the country of India. Each approach varies up to certain extent as far as concern the data and sampling in number and volume with respect to geo hydrologic condition of various study area. The groundwater samples are collected sites as per standard method of AHPA looking to the objective of study. The samples taken from different sampling sites can be analyzed for various heavy metals such as Zinc, Copper, Lead, Cadmium and Iron as per the suggestions given by APHA standard. (T.S.R Umamageswari et al., 2016). Looking to various approach the source identification techniques, the hydrologic conductivities in x and y direction, effective porosity, lithology, depth of water table, recharge and rainfall of concerned study area are the basic need along with primary data collection of specific location and laboratory work.

V. SIGNIFICANT WORKS FOR IDENTIFICATION OF SOURCES OF GROUND WATER CONTAMINATION IN INDIA

A very less amount of research or literature is available on identification of sources of ground water contamination across the India among which some significant works in this field have been selected for discussion in Table 1.Amongst research done with in India, the work of Deepesh Machiwal et al. in Udaipur district which is in hard rock hilly terrain of Rajasthan (2015); Raj Mohan Singh et al (2004); Sophia Leichombam et al., (2016); the work of Jyoti Chaubey et al. at area lying between Yamuna and Krishni rivers (2017); Alexander Zaprozec, Co-ordinator and Editor of Project Working Group of IHP-V, (2002); Bithin data et al., (2009); the work of T.S.R Umamageswari et al. in Virudhunagar distirct in Tamilnadu (2016); findings of Ashish Kr. Dwivedi and Padma S. Vankar in Unnao, Uttar Pradesh (2014): Shiv Shankar et al., (2014) and Pooran S. Mahar et al.(2000) of Pant nagar U.P have proposed inverse model identifies unknown sources of pollution by using measured values of pollutant concentration at selected locations (2000) were cited in the Table 1 with detail outcome inclusive of their method/ Technique adopted for research.

Table:1 Significant Works for Identification of sources of ground water contamination in India			
TITLE of Research	**Method /Technique**	**Outcome/Remarks**	**Reference(Author)/ Publication**
"Identifying sources of groundwater contamination in a hard-rock aquifer system using multivariate statistical analyses and GIS-based geostatistical modeling techniques."	GIS-based geostatistical modeling And multivariate statistical analyses like principal component analysis (PCA), hierarchical cluster analysis (HCA).	Identified anthropogenic and natural sources of groundwater contamination.	Deepesh Machiwal, Madan K. Jha (2015). Journal of Hydrology. *ELSEVIER*.
"Identification of Unknown Groundwater Pollution Sources Using Artificial Neural Networks"	Artificial Neural Networks.	ANN can be used to solve the complex problem of unknown groundwater pollution sources identification. Remarks: As the number of the potential sources increases, the complexity of the problem increases and error become large. This method also depends on no. of observation wells.	Raj Mohan Singh, Bithin Datta, and Ashu Jain, (2004). Journal of water resources planning and management. *ASCE*
"Identification of Unknown Groundwater Pollution Sources and Determination of Optimal Well Locations Using ANN-GA Based Simulation-Optimization Model"	ANN based simulation-optimization model.	Unknown groundwater pollution sources location.	Sophia Leichombam, Rajib Kumar Bhattacharjya, (2016). Journal of Water resource and protection. *SCIENTIFIC RESEARCH PUBLISHING*
"A data parsimonious model for capturing snapshots of groundwater"	Data parsimonious model and simulation-optimization model	Identification of flux from local sources like industrial and municipal effluents.	Jyoti Chaubey, Deepak Kashyap, (2017). Journal of Contaminant hydrology. *ELSEVIER*.
"Groundwater Contamination Inventory: a methodological guide"	Method of Office and field identification. Field investigations.	Determinied the extent and degree of existing contamination. the existing and potential contamination sources.	Alexander Zaprozec International Hydrological Programme within Project 3.1 IHP-V, (2002). *UNESCO*.

TITLE of Research	**Method /Technique**	**Outcome/Remarks**	**Reference(Author)/ Publication**
"Simultaneous identification of unknown groundwater pollution sources and estimation of aquifer parameters"	Linked optimization –simulation approach.	Large aquifer parameters and pollution source identification in terms of location.	Bithin data, dibakar chakrabarty, Anirban Dhar, (2009). Journal of Hydrology. *ELSEVIER*.
"Source Identification of Heavy Metal Contamination in Ground Water"	Multivariate statistical analyses like principal component analysis (PCA), clustering analysis (CA), and correlation analysis	Identification of heavy metal's anthropogenic and natural sources location of groundwater contamination.	T.S.R Umamageswari, D. Sarala Thambavani,(2016) Journal of Advanced Chemical Sciences. *JACS*
"Source identification study of heavy metal contamination in the industrial hub of Unnao, India"	Multivariate statistical analyses like principal component analysis (PCA), clustering analysis (CA), and correlation analysis	Identification of heavy metal's sources location of groundwater contamination.	Ashish Kr. Dwivedi & Padma S. Vankar, (2014), Environ Monit Assess. *SPRINGER.*
"Arsenic Contamination of Groundwater: A Review of Sources, Prevalence, Health Risks, and Strategies for Mitigation"	Review analysis.	Review of sources, speciation, and mobility of global overview of groundwater contamination. Also reviews the human health risks, its uptake, metabolism, and toxicity mechanisms. Overview of the problem of contamination of groundwater.	Shiv Shankar, Uma Shanker, and Shikha, (2014). The Scientific World Journal *Hindawi Publishing Coroporation.*
"Identification of Pollution Sources in Transient Groundwater Systems"	Nonlinear Optimization Model	Ground water pollution sources location under the condition of transient flow and transient transport.	Pooran S. Mahar, bithin datta, (2000). Water Resources Management. *Kluwer Academic Publisher.*

VI.DISCUSSIONS AND CONCLUSIONS

We sincerely wish that this review study will be functional to researcher in their research activity in this field. The paper reflects the latest state of understanding of various interdisciplinary facets of the problem of various pollution parameters in ground water and its sources.

It is observed while literature study carried out so far that there are few methods applied in majority of research which may be check with the help of alternative worldwide accepted another model to minimize the limitation of multivariate statistical analysis and GIS based geostatistical modeling.

Limitations of ANN method in terms of large identification errors are also noticed in the illustrative problems for the source of contamination in moderate or small study area. Therefore, ANN model can only be efficiently used as an approximate simulator for a large study area. However, in the light of soft computing technique and availability of more diverse, accurate and reliable data analysis GIS based geostatistical modeling have better scope of application for pollution source identification.

From the results obtained in terms of sources of contamination, it can be retained for further dispersion in ground water by various actions in order to minimize the risk on public health.

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