Groundwater Contamination study in the vicinity of Waste Disposal Ground using integrated approach of Aquifer Characterization- A case study from Dadu Majra, Chandigarh, India

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Abstract: *Groundwater being an important source of drinking water, its quality has become a prime concern due to increased pollution. Difficulties in groundwater studies are due to large and complex aquifer systems cannot be observed and high spatial variability of aquifers. Chandigarh for its daily consumption depends mostly on groundwater and demand is ever increasing. In Chandigarh mmunicipal solid waste is dumped in the open ground on the outskirts causing contamination of groundwater. A 45 acre open and 22 years old disposal site close to Dadu Majra was chosen to characterize aquifer and impact of landfill leachate on the groundwater and to assess its suitability.*

In addition to prior reports, secondary data regarding site were collected. Ground truth and groundwater samples from deep tube wells and hand pumps were collected in the vicinity of the area. Digital Elevation Model of the Chandigarh was generated using ArcGIS to know sloping pattern. The spatial variation of aquifer properties used to characterize for understanding groundwater flow and solute transport as hydrogeological settings is heterogeneous in the area. This involved analysis of borehole logs and hydraulic testing data to determine nature and origin of the strata, and their hydraulic properties. Depth of aquifer and sequence of layers consisting of clay, intermittent sand, gravel and boulders could be established based on subsurface lithological profile of the area generated from the borehole log data. Top clay layer followed semi confined aquifer up to 30 m underlying clay. Between 100 to 150 m there are 3-4 aquifer layers found in sand and gravels. The average hydraulic conductivity for deep tube wells was found to be 20 m/d.

Physical, chemical and biological forces act on or react with the migrating leachate, resulting in changes of chemistry. This spot has become not only breeding ground for flies, rodent, and pests but waste stored on land has become a part of the hydrological cycle. The situation is further deteriorated due to precipitation leading to contamination of GW through leachate percolation. Various properties like pH, hardness, turbidity, dissolved oxygen, BOD were determined using conventional laboratory tests. Impurities (pollutants) heavy metals – Pb, Ni, Fe, Cu, Cr, Bi, As were analysed using AAS. Deep tube well samples fall in the hard and hand pump samples in the very hard water category. The concentrations of Pb, Fe and Cu was found be high for hand pump samples than standard prescribed limits for drinking water and thus is not safe. In deep tube well samples Pb concentration is found be higher.

The aquifer characterization helped in understanding effect of hazardous material finds it path to groundwater primarily due to hydraulic conductivity. Hence, geology has a clear influence, with boreholes exploiting alluvial aquifers. The water samples of the deep tube wells are suitable whereas hand pump samples located at shallow depth are contaminated and thus require precautionary measures. Thus, it is concluded, groundwater quality improves with the increase in depth and distance from the pollution source due to dissolution of surface pollutants and percolation of Leachate. The study will help decision makers to take necessary remedial actions to solve the problem and in future planning and management for which continuous monitoring is need of the hour.

Keywords: Groundwater, waste disposal ground, Leachate, aquifer characterization, deep tube wells

1. Introduction:

Groundwater is an important source of drinking water for more than half of the nation's population and nearly all its rural population. In recent years, widespread reports of pollutants in groundwater have increased public concern about the quality of groundwater. Difficulties and uncertainties in groundwater studies are due to GW may occur in large, complex aquifer systems, it cannot be readily observed and aquifers have high spatial variability of its characteristics.

The city of Chandigarh for its daily consumption of water depends mostly on groundwater and future consumptive use of groundwater will increase. If the resource is not adequately understood and effectively managed, this might cause spatial or temporal water scarcity situations. Therefore, essential information related to basic aquifer properties will help in understanding groundwater volumes, flow rates and directions, or extent of interaction with surface water. Although waste lands being used for dumping are an indispensable part of everyday living, they may present long-term threats to groundwater that are hydrologically connected. A number of forces may act on or react with the migrating leachate, resulting in changes of chemistry and a general reduction of strength from the original release. These forces are physical, chemical and biological. The extent of these reactions depends on the materials underlying the waste lands, the hydraulics of the groundwater system, and the chemistry of the leachate and may lead to increase in toxicity.

The present procedure adopted by MC is after dumping waste; it is treated with EM Solution and was found to be helpful in the acceleration of decomposition process of the garbage, reduction in the volume of gas discharge with the result that foul smell has substantially minimized, minimization of larva of flies & mosquitoes. Thereafter leveling is done. Protecting our water resources is of paramount importance thus assessing the groundwater contamination in the vicinity of the waste lands should form part of the planning and management. Considering these facts present investigation is carried out with objectives; to evaluate the existing waste management practices in Daddu-Majra, characterize the leachate & groundwater, to investigate impact of landfill area on groundwater regime and to assess the suitability of ground water for various purposes. The study will contribute by detecting any contamination, if any, early in time for decision makers to take necessary remedial measures

1.1. Risk that waste disposal presents to groundwater quality and the review of the studies:

A significant increase in municipal solid waste (MSW) generation in India during last few decades and its management has become a major issue because the poor waste management practices affect the health and amenity of the cities. With rapid urbanization, the situation is becoming critical. Disposal of waste is the most neglected area and the current practices are grossly unscientific. Almost all municipal authorities deposit solid waste at a dump-yard situated within or outside the city haphazardly and do not bother to spread and cover the waste with inert material. These sites emanate foul smell and become breeding grounds for flies, rodent, and pests. When waste is stored on land, it becomes a part of the hydrological cycle. These waste disposal grounds present a significant threat to ground water resources due to their nature of operation and shear numbers. Simplistically, leachate is generated by precipitation percolating through a waste land and removing soluble components of the disposed waste.

R Feeze and Cherry [8] reported that chloride ion concentration is usually the best indicator for detecting the presence of leachate in groundwater. The results of effect of daily consumption of leachate-contaminated groundwater for 65days on rats' and contaminated groundwater may lead to ill health particularly anemia [4]. Landfill pollution potential index (LPPI) using the Delphi technique and an aggregation of six pollution indices that have already been developed for the quantification of different environmental elements in Delhi [10]. While others

Carried out analysis, assessment and mapping of groundwater quality of Chandigarh [7]. Evaluation of the leachate pollution potential and its impact on geochemical status of groundwater in areas around the MSW site, Pune was carried out on 28 physico-chemical parameters,10 heavy metals during post and pre monsoon seasons to calculate LPI [9]. Municipal Solid Waste Management in Asia-A Comparative Analysis study was carried out in 2003 [1]

Leachate produced from waste dumping sites is heterogeneous and exhibits huge temporal and seasonal variations. LPI value can be used as a tool to assess the leachate pollution potential from landfill sites particularly at places where there is a high risk of leachate migration and pollution of groundwater [3]. The precipitation falling in landfill carries numerous contaminants from the waste to the adjacent areas as well as the strata below the waste due to formation of leachate. This creation of leachate presents a major threat to the current and future quality of groundwater. The release of hazardous and non-hazardous components of leachate may render an aquifer unusable for drinking purposes and other uses. Once leachate is formed and is released to the groundwater environment, it will migrate downward through the unsaturated zone until it eventually reaches the saturated zone. Leachate then will follow the hydraulic gradient of the groundwater system and thus render an aquifer unusable for drinking-water purposes. Characterisation of subcatchment aquifers in the Liverpool plains for the purpose of groundwater modeling was done [6]. Pete Wilson, James Strock, developed a guidance manual for ground Water investigation based on an aquifer testing for hydrogeologic Characterization [5] Martin Holland [2] carried out a Ph.D study on Hydrogeological characterization of crystalline basement aquifers within the Limpopo Province, South Africa.

Leachate impacts to groundwater may also present a danger to the environment and to aquatic species. Treatment of Solid Waste Management depends on composition of the waste. In India since bio-waste dominated, the degradation takes place intensively, generating highly polluted wastewater and an immense nuisance. NEERI [11] has reported that quantum of waste generation varies between 0.2-0.4 kg/capita/day in the urban centers and it goes up to 0.5 kg/capita/day in metropolitan cities amounting to about 1.15 lakhs MT of waste per day.

1.2. Location of the study area:

The increase in MSW generation in Chandigarh is also major cause of concern for the Dadu majra area from health and its management point of view. Waste collected by the municipal corporation is dumped in the open area in the outskirts of the city. This caused nuisance and other problems related to health and contamination of land, water and air resources. In Chandigarh the waste is dumped into a 22 years old dumping site located in Dadu Majra. It is a 45-acre open disposal site. The 3 basic Steps followed for the Disposal of Municipal Solid Waste in Chandigarh are dumping, spraying of EM Solution and leveling. Around 280 vehicles with different carrying capacity i.e 5 tonnes, 3 tonnes ,trolley of 1 ½ tones full of dispose waste on the ear marked dumping ground. In the present study, Daddu-Majra, landfills was chosen to ascertain the composition of waste / leachate, and its effect on the groundwater. For this intent, a MSW dumping site near Sector 38 in Daddu-Majra is selected (Fig. 1).

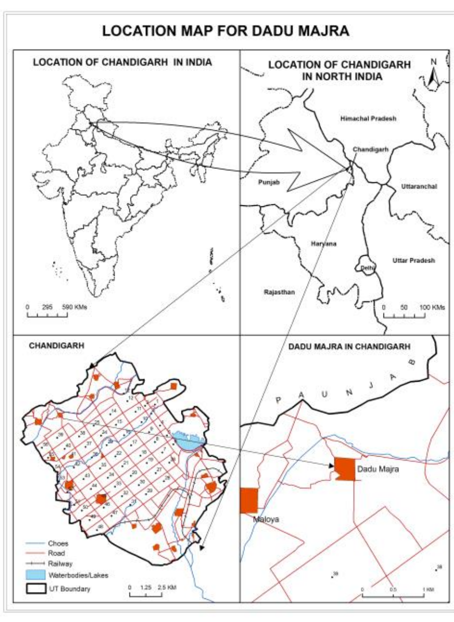

Figure 1 Location map of the study area

A close look of the garbage dumped on the waste disposal ground is in Fig.2.

Figure 2 Field photograph of the waste disposal ground, Dadu Majra, Chandigarh, May 2013

Study was conducted to understand groundwater contamination due to waste disposal so as to help its management and to take necessary remedial measures.

1.2. Lithological studies:

In view of the above spatial variation of aquifer properties must be characterized to develop accurate models of groundwater flow. The characterization should ideally involve (1) analysis of borehole logs and hydraulic testing data to determine nature and origin of the strata, and their hydraulic properties; (2) stratigraphic correlation of borehole logs in order to assess the lateral continuity of distinctive sediment types (facies) between boreholes; (3) use of geophysical profiles to assess the orientation and structural continuity of sequences of strata, (4) modeling of the geometry and distribution of sedimentary facies and (5) distribution of properties such as porosity and permeability as a function of sedimentary facies. Hydraulic conductivity is a key variable determining groundwater flow rates, hydraulic properties of geologic material at the sites. Hydrogeological settings are heterogeneous.

2. Materials and Methods:

2.1. Digital Elevation Model:

The Digital Elevation Model (DEM) of the study area was generated using Arc/GIS, 3D Analyst tool. The elevation data were taken from contours and spot heights as given in the SOI sheets. Digitization of contours and other heights helped in brining out sloping pattern of the study (Fig.3)

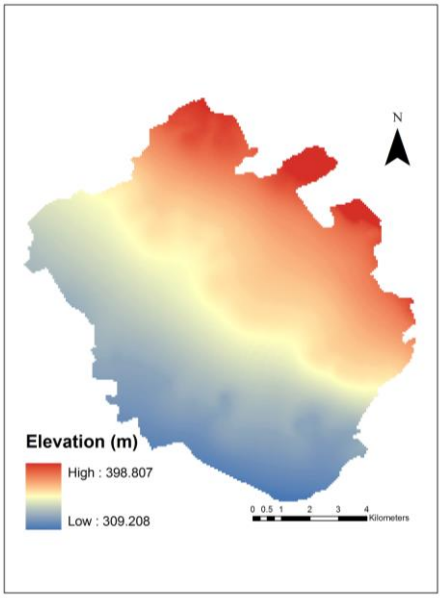

Figure 3 Digital elevation model of the study area

2.2. Establishment of Geologic Conditions:

Geological conditions were established using surface geology of the site and nearby areas, both locally and regionally using map of GSI (Fig. 4). Surface geological knowledge was used for deducing subsurface strata in the area.

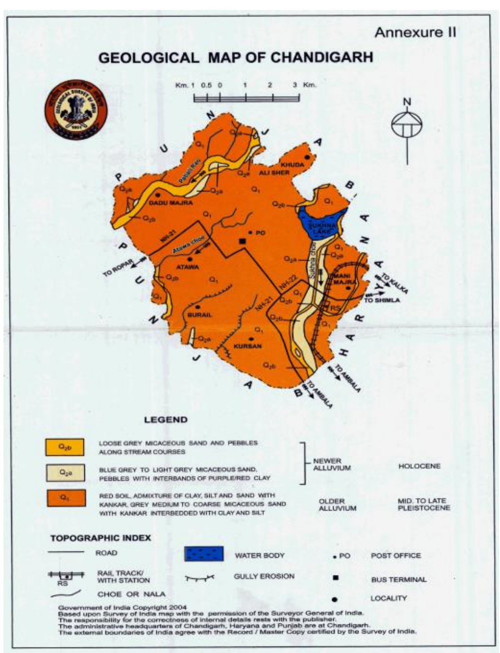

Figure 4 Geological map of the study area (GSI)

2.3 Land use & land cover map:

The land sue and land cover map of the area prepared by the Department of Space is shown in Fig 5 was used to demarcate major categories in and round the study area.

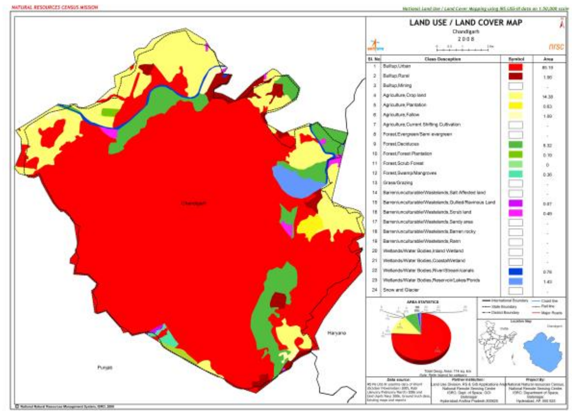

Figure 5: Land use Land cover map of Chandigarh (DOS, Bhuvan 2008)

Prior information and secondary Data were collected from Muncipal Corporation, sector 11D, regarding the site under study. Field Investigation included the selection of sampling site and collection of water samples from the tube wells and hand pumps for further analysis at relevant distance from the point source of pollution.

2.4. Lithological Model:

The subsurface lihtological profiles of the study area were prepared bore hole strata chart prepared from log data available in the vicinity of the study area. The cross sections were developed using RockWorks 14 software and hence subsurface profile of the Dadu Majra area was prepared.

2.5. Procedure of testing physic-chemical parameters:

Water samples deep tube wells and hand pumps were collected in the vicinity of Daddu Majra and were analyzed as per the prescribed standard methods. Pollution parameters falling under three categories were analyzed. Physico-chemical parameters- pH, Hardness, Turbidity, Dissolved Oxygen, Biological parameters – BO and Heavy metals testing - Lead, Nickel , Iron, Copper, Chromium, ,Bismuth, Arsenic. Parameters such as pH , Total Hardness, D.O, Turbidity were determined in the lab using standard tests. AAS was used determining concentrations of the heavy metals i. e Lead, Nickel, Iron, Copper, Chromium and Arsenic

3. Results and discussions:

From the geological map it is clearly established that the study area is predominantly occupied by the red soils, admixture of clays, silt and sand with kankar, grey medium to coarse sand interbedded with clay and silt. This is called as older alluvium and age is placed Pleistocene. From geological point of view Dadu Majra is considered as not very old strata.

DEM has clearly brought the general slopping pattern of the Chandigarh. In case of study area the slopping pattern decreases from NE to SW direction, the gradient being gentle (Fig. 3).

Although DOS data has misclassified study area under built land due to coarse resolution data as at 1:50,000 scale it is not feasible to demarcate such a small area, which was established by field checks.

3.1. Groundwater characterization:

From the subsurface profile of the cross section as shown in figure is clear that at top clay is predominant along the entire cross sectional area. A semi confined aquifer is followed by several aquifer layers with thick corse sand/gravel/boulder layer occurs at 100 to 150 . This aquifer being close to *choe (Patiali –ki-Rao)* is considered as good aquifer.

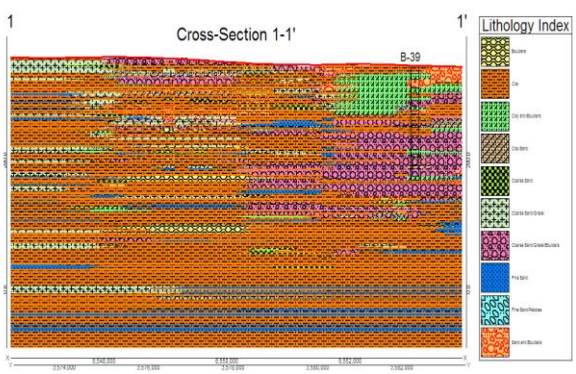

Figure 6 Cross sectional profile along Dadu Majra- Saragpur axis

3.2. Physico-chemical analysis:

The analysis for pH, Total Hardness, in samples of groundwater drawn from Hand pump and tube wells was carried out. The results of various inorganic constituents in the water samples taken from tube well representing deeper water zone and hand pump representing shallow water zone have been tabulated and placed in Table 1a and table 1b respectively.

Table 1a: Results of physico-chemical parameters in tube well water

S.No	Test performed	Value obtained	Permissible limit	Conclusion
1	pH	7.10	6.5 -8.5	Fit for drinking
2	Turbidity	Nil		Fit for drinking
3	Hardness (mg/l)	22	300-600	Fit for drinking
4	Dissolved Oxygen mg/l	8.5		Fit for drinking

Table1b: Results of physico-chemical parameters in hand pump water

S.No	Test performed	Value obtained	Permissible limit	Conclusion
1	pH	6.2	6.5 -8.5	Not fit for drinking
2	Turbidity	225		Not fit for drinking
3	Hardness (mg/l)	1750	300-600	Not fit for drinking
4	Dissolved Oxygen mg/l	0		Not fit for drinking

From the table 1a and 1b it is revealed that waters occurring at different depth are acidic or alkaline in this area, however falls in permissible limits 6.5-8.5 determined by Indian I.S -10500,1991. The pH affects the solubility of other water quality contaminants. Total Hardness of the tube wells is with in the limits where as hand pump TH is 1750 and thus categorized as very hard water

3.3. Heavy metal analysis:

From table 2 as given below it is evident that lead concentrations being 20 ppm and 30 ppm as found in the groundwater samples of tube well and hand pump (residential area near landfill) respectively is not fit for drinking. Nickel and chromium pose no problem for both samples drawn from tube wells and hand pump. However, Iron being slightly higher than the permissible limit in case of hand pump also does not pose any problem except it imparts bitter taste. Further, higher concentration of copper and arsenic in the hand pump sample is really a cause of concern. Since all the constituents being present in higher concentrations in hand pump sample water should not be allowed to draw from it are not safe for domestic purposes. However, groundwater drawn from tube well needs treatment before domestic use to higher concentration of lead.

. **Table 2: Heavy metals present in the groundwater samples**

S.No	Element	Tube well	Hand Pump	Desirable Limit	Permissible Limit in the absence of alternate source
1	Arsenic	Nil	10 ppm	0.01 mg/l	No relaxation
2	Iron	Nil	1.5 ppm	0.03 mg/l	1.0 mg/l
3	Chromium	Nil	Nil	0.05 mg/l	No relaxation
4	Nickel	Nil	Nil	0.02 mg/l	0.05 mg/l
5	Lead	20 ppm	30 ppm	0.05 mg/l	No relaxation
6	Copper	Nil	5 ppm	0.05 mg/l	1.5 mg/l

Presence of heavy metals in the groundwater can cause neurological disorders, disruption of renal function and cannot be degraded or destroyed. To a small extent they enter our bodies via drinking water. Heavy metals enter to water supply by industrial and consumer waste.

4. Conclusions:

From the above study it is concluded that
i) Being alluvial terrain of recent origin study area contains sand, silt and clay and subsurface boulders are encountered. Area in general is slopping gently towards SW direction.
ii) From the aquifer characterisation studies and physico-chemical studies it is clear that a) the overall quality of groundwater is contaminated due to infiltration and percolation of Leachate. b) groundwater quality improves with the increase in depth and distance from the waste land area (pollution source) and c) water samples in deep tube wells are suitable for domestic purposes except higher lead concentrations d) The presence of heavy metals clearly indicates the presence of inorganic contaminants in water.
iii) Whereas hand pump samples located at shallow depth show significant level of contamination and are not within the permissible limits for human consumption

5. Remedial measures:

From the groundwater monitoring is it clearly evident that the leachate generated from waste land area site is affecting the groundwater quality in the adjacent areas through percolation in the sub-soil. Therefore, some remedial measures are required to prevent further contamination. The management of the leachate within the landfill has already been initiated by the MC as this being the one of the effective controlling leachate. Industrial waste into the landfill should be prohibited as it adds inorganic contaminants to the groundwater regime. Strictly enforcement may be made to avoid using groundwater drawn from hand pumps located in close proximity of the waste dumping site. Efforts should be made to supply clean water through pipelines from distant sources. In addition to periodic monitoring of groundwater public departments should create awareness among the people.

6. Acknowledgment:

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