Application of Light Interference Technique for Locating Groundwater Veins

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Abstract. Water is one of the most needful resources on Earth. The increasing population, growing urbanization, and enhanced industrialization over the years have led to increased demand for water all over the world, causing a scarcity of resources and thereby made the world dependent on other sources of water than surface water. Among all, a majorly available and reliable source is groundwater. With diminishing groundwater levels, it endures the need for precise groundwater exploration. The groundwater investigation has been a more significant issue during the last few years due to intolerable distraction, deprecating water quality, and emerging pollution threats to potable resources. To overcome limitations of contemporary groundwater exploration methods present study proposes a new technique utilizing the 'Light Interference Technique,' a concept from fundamental Physics. An instrument, NaAvmeter, developed based on Light Interference Technique, was used for groundwater exploration in the current study. A literature survey shows that earth radiations are much dominant over groundwater locations. Empirical investigations were carried out in the Pune city under various site conditions to check the feasibility of application of 'Light Interference Technique' for groundwater exploration in the Deccan trap flood basalt terrain. An attempt is also made in the current study to propose a simplified groundwater exploration method using NaAvmeter; an instrument developed based on the 'Light Interference Technique.'

1. Introduction

There is a growing concern over freshwater all over the world. It is unavoidable that the pressure is and will be on the detection of subsurface water storage [1]. From the literature, it has observed that most groundwater (GW) exploration work that has been carried out from ancient times involves fieldwork and the use of knowledge gained from ancestors, limited to the local area. However, from the starting of the 19th century, significant updating in utilizing the various GW exploration methods has been observed [2]. As the cost of water exploration through modern methods is invariably unaffordable for the average person, traditional knowledge of exploring water sources is still in vogue among many rural and urban communities. In the recent past, science and technology have taken long strides in exploring GW as a result of which many techniques are available now to identify the GW [3]. The main focus of current research is to develop a GW exploration method that utilizes modern
techniques. The present study attempted to use an instrument designed based on light interference technique for GW exploration in the study area as an alternative to current GW exploration methods.

2. Background of GW exploration

The literature survey shows that many methods/techniques exist for GW exploration. Various techniques, methods available for GW exploration are as shown in Figure-1.

![Groundwater Exploration Methods](image)

**Figure 1.** GW Exploration Methods

2.1. Esoteric method

An esoteric method is practiced from ancient times. It considers the human body as the sensor for the detection of earth radiations caused due to movement of GW. It utilizes various instruments such as dowsing rods, Y-twig, coconut, pendulum, etc. The excessive Earth radiations at the surface of the GW location cause deflection to the instruments. Also, it makes use of knowledge of bio-indicators such as flora and fauna for the identification of GW at places.

2.2. Subsurface method

It is destructive testing, which involves borehole logging, drilling of cores, and interpreting the obtained data to explore the GW. Stratification is determined from the acquired data, and accordingly, traces of GW are determined at particular locations. Accuracy of results is high but is uneconomical considering field test setup and data interpretation.

2.3. Surface method

Surface method is a non-destructive type of testing. Unlike subsurface method, stratification is determined by using geophysical techniques such as ERT, SRT etc. without disturbing to the ground surface. Along with the other applications, one of the significant forms of the surface method is GW exploration. It ensures much reliable and accurate results of GW exploration due to which it is widely accepted all over the world. Undoubtedly cost is a significant disadvantage.

2.4. Aerial method

It includes airborne surveys and electromagnetic surveys for identification of GW potential zones. The data from such studies and other mapping details like thermal imaging, topography, drainage
pattern, etc., are overlapped together, and a thematic map is generated. Thematic map shows the exact locations of GW potential zones. It covers large area. The method is uneconomical in terms of the requirement of large setup, skilled supervision for data collection, and interpretation.

2.5. Mathematical modeling

Mathematical modeling for GW exploration comprises of artificial neural networking and fuzzy logic modeling. It is data-based coding that works on a system of input and output layers. It performs an input-output mapping via a series of simple processing nodes or neurons. A layer represents a set of parallel processing units (or nodes). Fuzzy-logic modeling gives the output in the range of 0 to 1, where the nearest value to 1 shows the maximum probability of the GW zone and vice versa. This method requires substantial data sets and highly skilled personnel for data interpretation. The accuracy of results highly depends upon the input data.

The research findings related to the various GW exploration methods have bought out certain characteristic deficiencies while adopting them in the field. It appears that the contemporary exploration methods are more efficient in terms of accuracy, speed, field coverage, field data interpretation that gives a realistic location for GW yield. Although traditional methods are offering human-body specific results and have limitations regarding quantification, the success ratio for utilizing these methods in the field is significant.

| Sr. No. | GW Exploration method | Cost for field work | Effect of Season | Field Test setup | Cost for data interpretation | Mathematical model | Dependency on other test | Field Result Repeatability | Result Accuracy |
|---------|------------------------|---------------------|------------------|------------------|----------------------------|-------------------|-------------------------|--------------------------|----------------|
| 1       | Esoteric Methods       |                     |                  |                  |                           |                   |                         |                          |                |
| a.      | Water Divining         | Less                | Slight           | Small            | Small                     | Not Available     | High                    | Medium                   | Medium         |
| b.      | Biological Indicators  | Less                | Slight           | Small            | Small                     | Not Available     | High                    | Less                     | Less           |
| c.      | Biophysical Methods    | Less                | Slight           | Small            | Small                     | Not Available     | High                    | Medium                   | Medium         |
| 2       | Surface Method         |                     |                  |                  |                           |                   |                         |                          |                |
| a.      | Geological and Geomorphological | Medium | Medium | Small   | Large | Available | Less | Medium | Medium |
| b.      | Hydrogeological        | Medium              | High             | Small            | Large                     | Available         | Less                    | Medium                   | Medium         |
| c.      | Geophysical Techniques | Medium              | High             | Medium           | Large                     | Available         | Less                    | High                     | High           |
| 3       | Subsurface method      |                     |                  |                  |                           |                   |                         |                          |                |
| a.      | Test Drilling          | High                | Medium           | Large            | Medium                    | Available         | High                    | High                     | High           |
| b.      | Tracer Technique       | High                | High             | Medium           | Less                      | Available         | Less                    | Medium                   | Medium         |
| c.      | Geophysical Logging    | High                | High             | Large            | Large                     | Available         | Less                    | High                     | High           |
| 4       | Aerial Method          |                     |                  |                  |                           |                   |                         |                          |                |
| a.      | Remote Sensing and GIS | High                | Slight           | Large            | Large                     | Available         | High                    | High                     | High           |
| b.      | Aerial Geophysical survey | High            | Slight           | Large            | Large                     | Available         | High                    | High                     | High           |
| 5       | Mathematical Methods   |                     |                  |                  |                           |                   |                         |                          |                |
| a.      | Artificial Neural Network | Small             | Slight           | Small            | Large                     | Available         | High                    | High                     | High           |
| b.      | Fuzzy Logic Technique  | Small               | Slight           | Small            | Large                     | Available         | High                    | High                     | High           |

**Legends:**
- Most Preferred
- Acceptable
- Not Acceptable

**Figure 2.** Comparison of the various GW exploration methods

Observing the essentiality of GW utilization, the development of various simple methodologies, instruments is a societal need. Currently, available different destructive, non-destructive methods, techniques, devices for GW exploration are much lengthy, expensive to operate, time-consuming, and complicated to interpret the results. Also, if there are any special field issues, then the use of various techniques in combination increases the cost, complexities in result interpretation and reliability on other field or laboratory tests. Handling several experimental setups on the ground at a time is also very cumbersome. Various researchers have attempted combinations of Esoteric,
Surface, Subsurface, Aerial, and Mathematical methods of GW exploration for identifying the zones of GW with certain limitations. Figure-2 shows the comparison of various GW exploration methods.

A primary objective of the proposed study is to explore GW with accuracy and economy, taking into accounts the GW exploitation due to increased demand. While developing this objective, the literature review shows that in current practices, many techniques exist for GW exploration. All exploration techniques have advantages and disadvantages in a particular domain (Figure-2). An attempt is made in the current study, to develop a method for GW exploration using the interaction of light with earth radiation for investigation of GW and which will also overcome limitations for contemporary practices.

3. Light Interference Technique

Many researchers have exercised the combination of various GW exploration techniques successfully. However, site conditions, financial aspects, the requirements of accuracy, and urgency of the result required, knowledge of an expert are the various factors that limit the execution and correctness of the exploration method employed. A fundamental concept of 'Light Interference' from Physics was observed to have the potential to be utilized for the exploration of GW. The idea was further elaborated to develop an instrument, NaAvmeter, for GW investigation [4]. Prima facie it has observed that the limitations of contemporary GW exploration methods have addressed while developing and utilizing the instrument. Figure-3 shows the field setup of the NaAvmeter.

3.1. Construction of NaAvmeter

NaAvmeter is a rectangular wooden box having a 1.0m length between the source and the receiver on the sides of the box. Materials that are attenuating the magnetic field are avoided, such as metals or polymers. The gap between source and receiver is for the interaction of the light beam emitted from the source. The source is a monochromatic coherent Laser beam produced by a semiconductor diode which travels and falls on selenium photodiode used as a detector. The selenium diode and current meter are connected to measure the current of the laser beam falling on the selenium diode [5].

3.2. Earth radiations

In the Earth's crust, there exist several natural fields such as Gravitational field, Magnetic field, Electric field, Radioactive field, Seismic field, Geothermal field, Geochemical field [6]. A variation in one or more of these fields may have some detectable effects. Some radiations are excited from the Earth's surface toward the underground, and after reaching a specific impedance interface, they
reflect and return to the ground surface. Thus, by identifying these waves, the exact depth of the impedance interface can be calculated. The transmitted radiation pulses are a complex combination. After reflecting from underground to the ground surface, waves reflect the various underground media characteristics [7]. One school of thought had elaborated that there exist such earth radiations at the location where GW is existing [5]. These earth radiations are having electromagnetic nature and are measurable [8, 9]. Scientists have observed that at GW zones, these earth radiations are significant, and at the location where GW is absent, these radiations are not substantial. Due to the various absorption effects of ions contained in the GW, it gives rise to the Earth's radiation. Specific metallic ions or metal particles contained in GW or flowing in streams through the rock mass, sand, soil strata of the natural ground are inducing an electromagnetic field [7].

3.3. Concept of NaAvmeter based on Light Interference Technique

The reflection and refraction of light are well-established from the literature. Laser exhibits the same behavior as that of ordinary light despite having unique properties like coherence and monochromaticity. The Earth's surface has an electromagnetic field in addition to various complex Earth radiations. Literature mentions that light in any form can bend when it passes the neighborhood of an electrically or magnetically charged object [10]. One stream of thought is that, in the presence of the electromagnetic field, the 'Delbruck scattering' effect causes the Laser photons to disintegrates into charged electron and positron for a shorter period. These charged electron and positron recombines into Laser photons after having interaction with the electromagnetic field. There is more probability of producing more photons due to such recombination causing scattering of light and thus causing light splitting into several rays [11].

Another stream of thought is that, at GW locations, the existence of earth radiations is evident, which may cause electromagnetic radiation tending to deflect the laser beam [5]. By this strong motive, an instrument, NaAvmeter, has been developed by combining the concept of Light Interference at the field to identify the locations having perturbations in the geo-electromagnetic field, resulting in GW locations.

NaAvmeter has a gap between the Laser light source and a selenium photodiode detector. Selenium diode converts light into electric current, and the indicator displays the output in terms of intensity of electrical current or intensity of light. In the case of perturbation in geo-electromagnetic fields are existing in this gap, then interaction occurs between photons of Laser light and geo-electromagnetic fields, which changes the output of the detector. If no perturbations in the geo-electromagnetic fields are present in the gap of source and detector, then no interaction occurs; hence, the output of the sensor remains the same on the field [4].

4. Use of NaAvmeter to identify GW locations

The methodology utilized for locating GW zones comprised of water dowsing that has been well established since ancient times. L-rod dowsing is well-known in the GW location study. The well-established electrical resistivity method (ERM) can be utilized to confirm the existence of GW. The presence of GW is evident by data processing of ERM results using master curves. Similarly, NaAvmeter can also be used in the identified locations to explore the existence of GW. The following procedure shall be adopted at the field to locate GW zones using NaAvmeter [9].

- A grid of around 10m×12m shall be plotted around the location under consideration.
- Five (05) profile lines at an interval of 3.0m aligned in North-South direction and each profile line with eleven (11) grid points at a range of 1.0m shall be marked.
- NaAvmeter readings shall be recorded at each grid point.
- Following the mentioned procedure, readings shall be recorded for each grid point of each profile. For one location under observation, five profile readings shall be recorded. In this way, field readings using NaAvmeter shall be filed at all sites under consideration in the field.
Duration of keeping NaAvmeter at a point while taking readings is one of the significant affecting factors. Experience gained through field observations, saturation in the NaAvmeter readings was observed after 2-3 minutes keeping at the place. Hence, readings shall be recorded after three (03) minutes of keeping the NaAvmeter at the location.

NaAvmeter readings then shall be graphed using suitable contour plotting software for the readings observed for all rotations on that particular grid point in the study area. The graph plots show distinct variation in NaAvmeter readings based on which GW location can be identified.

5. Application of NaAvmeter in the field

The basic working of NaAvmeter has discussed above. The emission of earth radiations and interacting with the laser beam in the NaAvmeter causing a change in the value of current in microampere on the selenium photodiode detector of the NaAvmeter is, in fact, a very complex phenomenon. It has already established that earth radiations are in existence everywhere on the Earth's surface, however at the locations of GW zones, such earth radiations have measurable perturbations. Authors have used NaAvmeter successfully at various locations in the Pune region, i.e., in the Deccan trap flood basalt region.

5.1. The physical setting of the Study Area in the Pune region

The study area is situated in the valley of Mula–Mutha rivers on typical rugged Deccan volcanic topography. The mountain and hill range in the West, river basins with undulating topography at the center, and in the East highland plateaus with more extensive river basins mark the physical landscape of the region [12]. In the West of the study area, the average height is about 900m above sea level [12]. The entire study region of Pune is mainly formed by two major parts of the Western Ghats, and 2,000m thick layers of Deccan volcanic basalts formed 65 to 70 Mya during the Late Cretaceous period [13]. The plateau after the catastrophic phase of faulting has remained relatively stable and has undergone a succession of cycles of erosion [14]. The region has a basaltic base on which there are alluvial deposits in river valleys on the terraces and old flood plains. Fault lines have scattered throughout the Pune region, and these areas are minor earthquake-prone [12]. Alluvial deposits have observed on both the banks of Mula and Mutha rivers. The alluvium is about 5 to 15m thick. It has a lateral extent of over 2000m on both sides of the Mutha river. This alluvium also occurs in patches in the Paleo depressions [12].

The occurrence of GW in limited quantity within hard rock terrains such as volcanic Deccan Traps in Western India is well known. The main aquifer horizons of the Pune region are vesicular, fractured, and weathered basalts [15]. The inter-trap formations, such as red bole, also form aquifer horizons at places. The study area has the domination of zeolites as cavity fillings and veins in the basalt. Pores and voids of the natural zeolite structure have characterized by water molecules [16]. Seasonal GW level fluctuation analysis between pre-monsoon and the post-monsoon season for the year 2011 reveals that the rise in GW levels has found between 0.20m to 12.35m. In the major part of the Pune region in North-Western and South-Eastern part, GW level fluctuation is varying from 0 to 2m. The central and eastern part of the Pune region has a variation between 2m to 6m. GW level fluctuation of more than 6m has observed in isolated pockets. Falls in the GW level between pre and post-monsoon season of the year 2011 has also seen at various places, and it varies from 0.05m to 2.00 m [17].

5.2. Locations identified for the current study

From the study area, two (02) sites have identified for conducting experiments. Details of the site have given in Table-1. An empirical investigation using NaAvmeter had conducted at the above-identified locations. Result interpretations using 'Surfer,' contour plotting software has been discussed in the following section.
Table 1. Details of field Locations.

| Location No. | Field Location | Satellite Locations |
|--------------|----------------|---------------------|
|              | Plot Number    | Latitude            | Longitude       | Altitude (m)  |
| 1            | RH-6 D         | 18°34'0.9"         | 73°32'40.9"    | 627           |
| 2            | D-7A           | 18°33'45.1"        | 73°32'20.5"    | 736           |

5.3. Interpretation of field investigation
The NaAvmeter readings show a decrease in current readings over the GW locations and show incremental readings over the non-GW zone. Figure-4 shows the contour plots of the NaAvmeter readings where contour legends are the representative of the same. On the color scale, blue color shows lesser NaAvmeter readings, whereas the red color shows increased readings. Literature indicates that there is a dominant zone of electromagnetic radiation at places of GW locations. It has also been seen in the form of a significant decrease in readings of NaAvmeter. From the field observations regarding geology, geohydrology, biological indicators, etc. confirms the GW potential at the locations. The same can be seen in the contour plots via distinguishing color scale. Blue colored zone is a clear indicator of GW zones at the places, whereas the red color zone indicates the probability of the non-existence of the GW zone. By considering all the parameters in the account, the location of the GW vein and its width can be easily identified.

![Figure 4](image_url)

**Figure 4.** GW zone identification using NaAvmeter at two locations under consideration

6. Summary
The two locations from the study area have been selected on the basis of availability of data and other geological, geomorphological, and geohydrological details. The preliminary investigation includes the collection of aquifer data, morphological data, biological indicators, availability of existing bore well point and its working condition, rainfall data, and respective GW fluctuation levels, etc. A brief study on the obtained data confirmed the presence of GW at the locality. NaAvmeter readings at both locations were taken by procedure elaborated in the above section. The obtained readings were then tabulated and interpreted using a contour plotting software ‘Surfer.’ Taking into account, contour plots and acquired field data, the exact location of GW has been identified.
7. Conclusion

Field experiments were conducted in the study area using NaAvmeter. One school of thought is that electromagnetic field perturbations due to the availability of GW may cause scattering of light while passing through such zones, which causes a decrease in current readings. The NaAvmeter readings recorded at the identified GW zone shows a sharp reduction in comparison with non-GW zone over remaining locations in the study area. The present work interprets the results obtained through NaAvmeter to provide a quantifiable result to identify the zones of GW. The contour plots give the quantification of GW veins in terms of its width, which can be used further to provide a borewell point for GW exploration. The current work contributes to the advancement of knowledge regarding the investigation of GW resources. NaAvmeter can be used successfully to identify the GW locations. Use of NaAvmeter avoids the practical limitations of contemporary GW exploration methods/instruments.

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