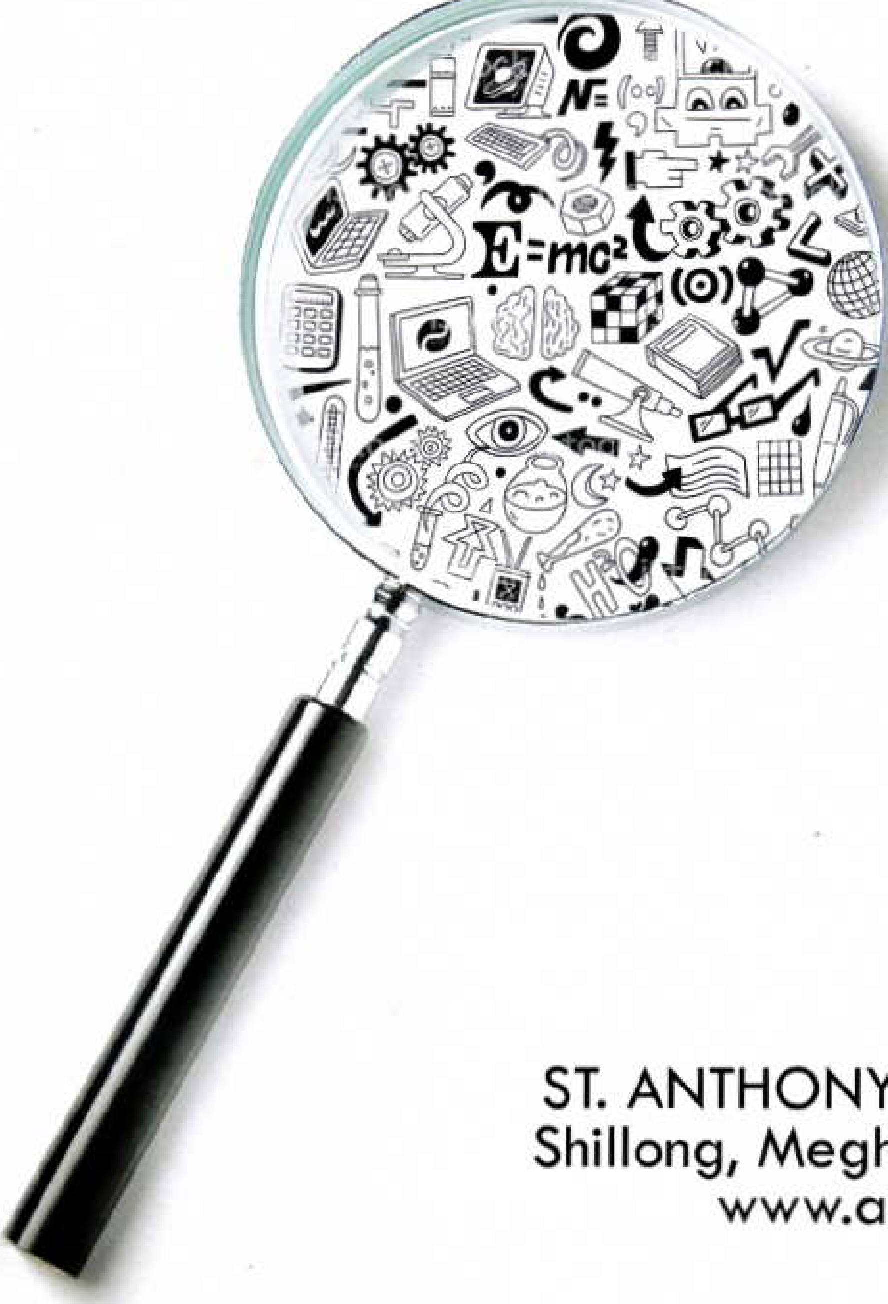
ISSN 2349 2937

spectrum

SCIENCE AND TECHNOLOGY

a peer reviewed journal

VOL. 4, 2017



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Shillong, Meghalaya, India
www.anthonys.ac.in

ISSN 2349-2937

Published at St. Anthony's College, Shillong

Editorial

Good team work by members of the editorial board has brought forth the fourth issue of Spectrum: Science and Technology. The six articles in this issue are from the life sciences, information technology, and geology.

The article on scientific fish farming highlights the need for imparting training to farmers of Meghalaya and demonstrating to them advanced fish farming techniques. The authors stress on the implementationof scientific fish farming methods to increase fish production in the state.

It is important to know the phytochemical constituents of plants so that their medicinal use can be optimized. An article reports the types of biologically active compounds present in two plant species known for their medicinal use.

Communications through wireless networkshave become part of our lives. Efficient use of energy by wireless networks has been the endeavour of researchers in the field of information technology. The findings of a study on dynamic clustering in wireless sensor networks havebeen presented in one article of the present issue.

An article reports the discovery of a frog species in Arunachal Pradesh. This animal was previously reported from several other locations of North East India. The authors aver that such finds have important bearing on taxonomy and population trends of species.

Effective elimination of bacteria from food, water, medical supplies and equipment has been a challenge for food industry as well as for the human health care sector. Authors of an article found variations in growth and survival of four different bacterial species after exposure to the same levels of UV irradiation and inferred that effective eliminationcan be obtained by utilizing a combination of different methods of sterilization.

Availability of potable water has been a major concern of humans around the world. A study on the chemical compositions of groundwater of Shillong city reveals that the samples varied in both content and concentrations of ions. Using standard analytical procedures the authors have graded the water quality of Shillong from excellent to unsuitable for drinking.

I have presented above glimpses intothe six articles and invite readers to read them in full in this issue of Spectrum: Science and Technology. The credits for improving the quality of manuscripts goto thereviewers and also to editorial board members. A special thanks to Prof. Thy Answer Challam, Prof. Jeremy N. Syiem. and Prof. Stevenson Thabah for devoting their valuable time and labour in the publication stage of thefourth issue of Spectrum: Science and Technology.

I, on behalf of the editorial board of Spectrum: Science and Technology and on my behalf thank Rev. Br. Albert L. Dkhar, Principal, Rev. Fr. Saji Stephen, Vice-Principal and Rev. Fr. Joby Joseph, Rector for their support and encouragement at all stages of the publication of the current issue of the journal.

Dr. M.A. Laskar
Chief-Editor

Contents

Data Correlation based Energy Aware Energy Efficient Dynamic Clustering (EAEEDC) in Wireless Sensor Networks

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Abstract

Wireless sensors are inherently energy constraint. A strategy that reduces energy consumption without affecting the accuracy of readings significantly is highly preferable. In densely deployed wireless sensor networks (WSN), sensor observations are highly correlated in space and time. In this paper, we present a data collection framework that utilizes these correlations to reduce the number of transmission from the nodes, and hence saving energy and increasing life of the wireless sensor network. The framework starts by accumulating the initial data to find the correlation and aggregate the sensors into set of clusters based on analysis of the surveillance data and geographical proximity of the sensors. Only two representatives from each cluster based on the residual energy take part in data collection at a given time slot while the others in the cluster remains in sleep mode. The framework also has the provision for dynamic adjustment of cluster if the sensors within the cluster are found to be dissimilar. The efficiency of the algorithm is evaluated through simulation and the results are found to be satisfactory.

Keywords: *wireless sensor networks, data mining, clustering, data-correlation, spatial suppression, temporal suppression.*

1. Introduction

Wireless sensor networks (WSNs) are being employed in a variety of applications ranging from military to industry. WSNs generate a large amount of data that can be analyzed using different analysis techniques. Among these techniques, data mining has recently received a great deal of attention to extract useful knowledge regarding WSNs [1]. Wireless sensor network has been identified as one of the most important technologies for the 21st century [2]. Recent advances in wireless technologies have led to the development of sensor nodes that are capable of sensing, processing, and transmitting physical parameters associated with the environment being monitored by the sensor nodes [3]. The individual devices in a wireless sensor network (WSN) are inherently resource constrained: They have limited processing power, storage capacity, communication bandwidth and limited battery power. These devices have substantial processing capability in the aggregate, but not individually. So, we must combine their many vantage points on the physical phenomena within the network itself [4]. Once deployed, the sensor nodes form a network communicates through short-range wireless communication. They collect environmental surveillance data and send them back to the data processing center, which is also called the sink node [5].

One of the major constraints of WSN is its energy consumption. Sensors are generally powered by a battery with limited life. Moreover, huge numbers of sensors in hostile environment makes it humanly impossible to replace these batteries after deployment. Therefore, techniques must be developed to reduce the consumption of power to prolong the life time of a sensor network while maintaining accuracy and reliability of the network.

Many types of sensor data exhibit strong correlation in both space and time. Both temporal and spatial suppression provides opportunities for reducing the energy cost of sensor data collection [6]. In most application scenario, reading of the sensors remains nearly same within a small time interval. In case of a temperature monitoring sensor used in habitat monitoring application is not expected to vary significantly within a minute. In such case, the node can suppress the transmission of data if its reading has not changed since last transmission, thus saving energy. Similarly, in case of sound detecting sensors, if one of the sensors has detected a sound, it is most likely that other sensors in its neighborhood will also detect the same sound. Reading of one sensor is sufficient to detect the phenomenon and transmission of the rest of the sensors can be suppressed.

Spatial and temporal suppression can be exploited better if the sensors are clustered based on data correlation rather than only geographical distance or network topology. Clustering is a process of grouping a set of data objects into multiple groups or clusters so that objects within the clusters have high similarity, but are very dissimilar to objects in other clusters [16]. Although node clustering is commonly used in WSN to group the sensor nodes, the use of data mining techniques to partition these nodes is rarely used. Thus, in most of the cases nodes in the cluster have no data correlation. In this paper, we present a framework for energy efficient data collection from wireless sensor network by utilizing spatial and temporal suppression.

Rest of the paper is organized as follows. Section 2 reviews related work. Section 3 outlines the basic techniques and terms used. Clustering algorithm and Scheduling scheme is presented in Section 4 and 5. Simulated results are presented in Section 6. Finally, we conclude the paper in Section 7.

2. Related Work

Node clustering technique is commonly used in wireless sensor networks. Most of the clustering techniques [14][15] available in literature till date in wireless sensor networks are mainly based on the network topology. Main aim of clustering sensors in this type of cluster is to route the data to the sink efficiently. Heinzelman et al[14] introduced LEACH (Low-Energy Adaptive Clustering Hierarchy), a clustering-based protocol that utilizes randomized rotation of local cluster base stations (cluster-heads) to evenly distribute the energy load among the sensors in the network. However, these clusters of sensors are formed based on signal strength and minimum communication energy. Similarly, Younis et al [15] proposed HEED (Hybrid Energy-Efficient Distributed clustering), that periodically selects cluster heads according to a hybrid of the node residual energy and a secondary parameter, such as node proximity to its neighbors or node degree.
Use of data mining techniques directly to cluster sensor nodes is also used to some extent [5][9][6][8][13][7]. Liu et al. proposed a dynamic clustering and scheduling approach called EEDC (Energy-Efficient Data Collection). The Cluster formation in EEDC is based on similar sensor readings (data correlated). That is member nodes of each cluster sense similar data. EEDC framework will be discussed in detail in Section III. Guo et al. [9] proposed H-Cluster, a distributed algorithm for clustering sensory data. They used Hibert Map to map d-dimensional sensory data into 2-dimensional area covered by a sensor network. Yeo et al. [6] proposed DCC (Data Correlation-based Clustering Scheme), algorithm based on similarity of sensor data. In DCC Yeo et al. modified the advertisement phase of HEED [15] to organize clusters by adjacent sensor nodes which have similar readings. Spatial suppression is performed at the cluster heads. Beyens et al. [7] proposed a new cluster-based approach where the cluster heads spatio-temporally correlate and predict the measurements of the cluster members by executing their prediction model. Taherkordi et al. [8] proposed a communication-efficient distributed clustering algorithm for clustering sensory data.

3. Preliminaries

Wireless sensor networks (WSN) are event based systems that rely on the collective effort of densely deployed several microsensor nodes which continuously observe physical phenomenon. The main objective of the WSN is to reliably detect/estimate event features from the collective information provided by sensor nodes [17]. These sensors are used to monitor some measures of interest specific to application. These measures include light, temperature, air pressure, vibration etc. Depending on the application, it may monitor one or more of these parameters.

One of the major concerns in WSN is the limited energy of these sensors which is typically powered by a battery. Due to the sheer numbers of sensors and their deployment in physically hostile environment makes it humanly impossible to recharge or replace its batteries. Due to this reason, one must develop a strategy to reduce the energy consumption of thesesensors to lengthen the lifetime of the network. Most of the energy of a sensor is spent while transmitting information to the sink. Moreover a sensor can be in two states: active mode when it is sensing or detecting events (more energy consumption) and sleep mode when it turns off sensing (less energy consumption). Our goal is to keep maximum numbers of these sensor nodes in sleep mode while maintaining the quality of data reporting.

It is observed that dense deployment of sensors is commonly used for better coverage of the environment. Such dense deployment often results in overlapping of the sensing range, i.e. more than one sensor cover a single area resulting in redundant data. For example in Figure 1, sensor t is redundant as neighboring sensors p, q, r, and s is already covering the same area. Intuitively, we can say that sensor t may be put to sleep mode to preserve energy and its reading can be predicted based on the readings from its neighboring sensors. However, imagine a situation where all these sensors in Figure 1 is used to monitor temperature in an environment and two of them are placed in sunlight whereas the other two are in shade. In such situation, it will be difficult to predict the reading of sensor t correctly because the sensors are related based on only coverage. In order to take advantage of spatial suppression, they must be correlated based on the data. The term suppression to refer generally to query independent techniques for reducing the cost of reporting changes in sensor values [19]. We outline the technique of spatial and temporal correlation suppression below:

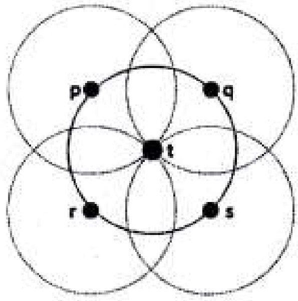

Figure1: Redundant Sensors Based on Sensing Range.

3.1 Spatial Correlation and Spatial Suppression

Typical WSN applications require spatially dense sensor deployment in order to achieve satisfactory coverage. As a result, multiple sensors record information about a single event in the sensor field. Due to high density in the network topology, spatially proximal sensor observations are highly correlated with the degree of correlation increasing with decreasing internode separation [17].

Once degree of correlation is established among proximal sensors, spatial suppression can be used to reduce energy consumption. Readings are reported by a sensor node over time form a time series. Suppose the time series of sensor x, y, and z are very similar in the past. Thus, we may assume that the readings of x, y, and z will likely be similar in the future. Thus instead of scheduling all three sensor nodes reporting data, we may suppress reporting of one or two of them resulting in energy saving while still maintaining the quality. These sensors may take turns to report based on some criteria.

3.2 Temporal Correlation and Temporal Suppression

Some of the WSN applications such as event tracking may require sensor nodes to periodically perform observation and transmission of the sensed event features. The nature of the energy-radiating physical phenomenon constitutes the temporal correlation between each consecutive observation of a sensor node [18]. The degree of correlation between consecutive sensor measurements may vary according to the temporal variation characteristics of the phenomenon [17].

Similar to spatial suppression, we may also use temporal suppression to save energy. Say for example, current sensor reading of a sensor has not changed since its last reported value. Thus, it can decide not to report its reading in that particular epoch and the base station can assume any unreported values remains unchanged.

3.3 Data-Correlated Clustering in WSN

Cluster analysis is one of the basic data mining techniques that can be defined as the process of organizing or partitioning a set of objects (observations) into groups or clusters so that objects within a cluster have the most similarity to one another and the most dissimilarity to objects in other clusters. There exist many algorithms for data clustering in the literature. Most of these algorithms are designed to deal with data which is stored in a traditional database. Clustering as a data mining tool has its roots in many application areas such as biology, security, business intelligence, web search, etc. [16]. However, its use in WSN is limited.

Cluster based sensor networks have proven to be more efficient and adaptive approach. Most of the cluster based mechanism is adapted for node communication and routing. In a clustered sensor network, nodes communicate only to the cluster head which aggregates data and delivers it to the base station or sink. As most of these clustering mechanism available till date is mainly based on the network topology and communication cost. Thus, use of suppression techniques cannot be used efficiently in this kind of network.

In this paper, our aim is to present technique of clustering sensor nodes base on the cluster analysis performed on the data generated by the sensor resulting in a data correlated cluster of sensors. Further, we use spatio-temporal correlation to schedule sensor nodes and suppression redundant data transmission.

4. The Energy Efficient Data Collection (EEDC) Framework

According to Liu et. al.[5], heavy duties in data collection design should be put on the sink node as sink nodes usually has much larger memory and more powerful computing capabilities and less energy constraints as compared to sensor nodes. EEDC framework follows the design principle as shown in Figure 2, where functionalities of the sink nodes are simple. The Scheduler module in sink node simply extracts the working schedules received from the sink node (based on clustering results) and makes the sensor node work/sleep according to the schedule.

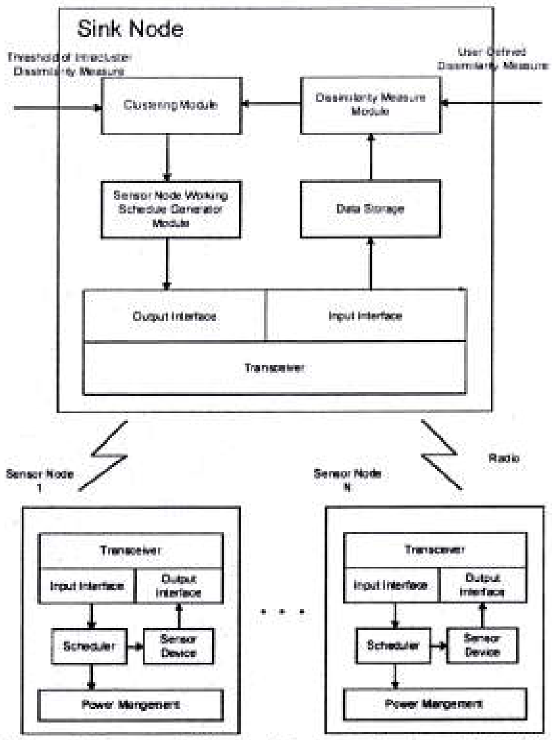

Figure2: Energy Efficient Data Collection (EEDC) Framework.

Data collection process with EEDC consists of three phases:

1) *Data accumulation:* Data collected from the sensor nodes in the sink. After collecting enough data, the sink node calculates dissimilarity measures between any two time series. It terminates this phase when dissimilarity measure among collected time series remains roughly stable. Two time series is separated into different groups if any of the following constraints is violated:

a) They have small difference in magnitude on average;

b) They have the same trends in most of time;

c) They are geographically close.

Two time series $X\{x_1, x_2, \dots, x_n\}$ and $Y\{y_1, y_2, \dots, y_n\}$ are magnitude m-similar if

$$\frac{\sum_{i=1}^{n}|x_i - y_i|}{n} \le m \qquad (1)$$

Two time series $X\{x_1, x_2, \dots, x_n\}$ and $Y\{y_1, y_2, \dots, y_n\}$ are trend t-similar if

$$\frac{n_1}{n} \ge t, \qquad (2)$$

where n_1 is the total number of pairs (x_i, y_i) in the time series that satisfy $\nabla x_i \times \nabla y_i \ge 0, \nabla x_i = x_i - x_{i-1}, \nabla y_i = y_i - y_{i-1},\ i > 1$.

Geographic distance between two sensors is similar, if they are within *gmax_dist*.

2) *Clustering:* Given the pairwise dissimilarity between sensors, they can be grouped into exclusive group or cluster such that pairwise dissimilarity of the sensors is below a given intra-cluster dissimilarity threshold *max_dist*.

3) *Saving and dynamic clustering:* In this phase, the sink node sends out the decision of cluster to all sensor nodes and requires the sensor nodes within the same cluster to work in turn to save energy. All sensors in the same cluster, detect similar data as they are correlated. Scheduling scheme is designed to collect data from only one sensor at any given time. For a cluster of k sensor nodes, time period T can be divided into k time slot where each time slot duration $=T/k$. Sink noderandomly selects a working schedule such that each sensor is active for the given time slot.

Also sink node monitor large variations within a cluster and dynamically adjust the cluster. The environment being monitored by a sensor may change over time. EEDC accommodate such changes dynamically. To achieve this, the sink node utilizes the fact that the dissimilarity measures from some sensors within the same cluster should not be larger than the give intra-cluster dissimilarity measure threshold. In the case where dissimilarity measure is found to be larger than the threshold, there is a need to split the existing cluster. To calculate the dissimilarity measure, there is need to quickly detect any spatial correlation. This is achieved by extending the working time of each sensor by Δt at the end of each time slot. During this period (Δt), sink receives sampling from two sensor nodes assigned to two consecutive time slot as shown in Figure 3.

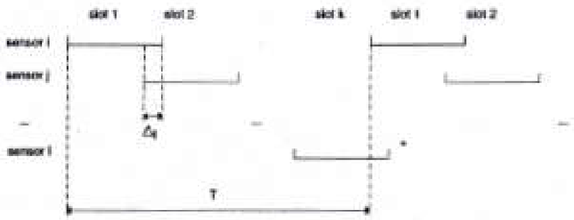

Figure3: Scheduling Scheme of EEDC.

It is obvious that the number of cluster will keep increasing as there is only splitting operation. In the worst case scenario, all sensors will be awoken to work simultaneously. To overcome this situation, sink node re-cluster the whole network when the current number of clusters becomes significantly large.

4.1 Clustering Sensor Nodes

Given the pairwise dissimilarities, the sink needs to group the sensors into clusters. Partitioning of the sensors can be performed using a clustering algorithm. Liu et al.[5] constructed a graph *G* such that each sensor node is a vertex in the graph. An edge (*u*,*v*) is drawn if the dissimilarity measure between the vertex *u* and *v* is less than or equal to the

```
Input: a graph G;
Output: a set of cliques covering the graph G;
Algorithm Description:
        Label all vertices in the graph G as uncovered;
        while (there are vertices uncovered in the graph G){
                Pick up the vertex v with the highest node degree among the uncovered vertices;
                Pick up all the vertices adjacent to v and put them into a list of S;
                Construct a graph G_tmp, consisting of only the vertices in S;
                Calculate the node degree of each vertices in G_tmp;
                Sort the vertices in S according to the decreasing order of node degree in G_tmp;
                (To break a tie, the vertex with lower degree in the original graph G precedes);
                Construct a clique C containing only v;
                while (there are vertices available in S){
                        Pick up next vertex s from S;
                        If s is adjacent to all vertices in C thus far, put s into the clique C;
                }
                Output clique C;
        Remove all vertices covered by C from the graph G;
        }
```

Algorithm 1. The Greedy Algorithm

intra-cluster dissimilarity measure threshold *max_dist*. Above mentioned problem is modeled as a clique covering problem in [5]. They proposed a greedy algorithm described in Algorithm 1.

5. The Energy Aware Energy Efficient Data Collection (EAEEDC) Framework

EEDC framework in [5], utilizes the data correlation to group sensor nodes into cluster. Therefore spatial suppression techniques could be utilized to save energy of the sensors resulting in longer network life. However, in EEDC framework, it does not consider residual energy of the sensor while assigning a sensor node to a time slot. All sensors are considered to have similar residual energy, which may not be the case in many cases. Moreover, only one sensor within each cluster is selected to be active at a given time slot. Thus it does not take care of the loss of data during transmission. If the sensor stops working due to any reason, there will be no sample received during that time slot. Also, Liu et. al [5] only uses spatial correlation and suppression to save energy, while temporal correlation and suppression can be also added to further save energy of the sensor nodes. In this paper, we propose an Energy Aware Energy Efficient Data Collection (EAEEDC) framework to overcome the limitations of EEDC. In EAEEDC, we also assume that all sensor nodes can directly communicate with the sink node.

1) *Data Accumulation:* Like EEDC, in this phase, each sensor node keeps sampling and transmitting samples to the sink node along with its residual energy. The sink nodes receive time ordered sampling and maintains a time series for each sensor node. After collecting enough data, the sink node calculates the dissimilarity measure between any two time series. It terminates this phase whenever the dissimilarity measure among the collected time series remains roughly stable.

2) *Clustering:* In this phase, the clustering algorithm separates sensor nodes according to the dissimilarity measure calculated in the previous phase. Output of the clustering algorithm is a set of clusters. Each cluster contains a group of sensors which detects similar environment and are in close proximity to each other. Observation of any region can be approximated by observation of any one of the sensor node within that cluster. EAEEDC follows the similar clustering algorithm of EEDC.

3) *Energy saving and dynamic clustering:* In this phase sink nodes sends its decision of clusters to all the sensor nodes and requires the sensor nodes within the same cluster to work in turns to save energy. The scheduling scheme at this phase activates two sensors instead of only one. Selection of the sensor is not random, but it chooses the sensors with highest residual energy to remain active. Since atleast two sensors are active at any given time slot, it need not extend the duration of the active sensor of the previous slot to calculate the dissimilarity measure. Also, we utilise temporal suppression, where the sensor will not transmit its reading if reading has not changed since the last reading. EEDC only has the mechanism to split the cluster to accommodate dynamic adjustment. Clustering algorithm in EAEEDC uses the technique of reassigning the sensor to another cluster if its dissimilarity measure is within the threshold. Splitting is performed only in situations when it cannot be assigned to any of the existing cluster. This prevents re-clustering of the whole network.

6. Simulation Results

It was assumed that the sink node is one hop away from all sensors. Real dataset has been used from data collected from 54 sensors deployed in the Intel Berkeley Research lab between February 28th and April 5th, 2004 (**http://db.csail.mit.edu/labdata/labdata.html**). Data contains about 2.3 million readings collected over the period. Only light in Lux (a value of 1 Lux corresponds to moonlight, 400 Lux to a bright office, and 100,000 Lux to full sunlight.) is used for the simulation. It was also assumed that the initial energies of all sensors are equal at the beginning of the simulation. Locations of the sensors are depicted in Figure 4.

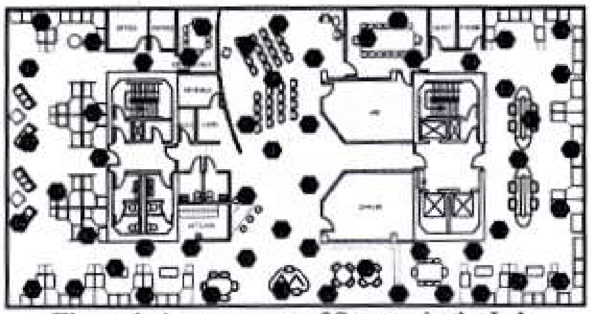

Figure4: Arrangement of Sensors in the Lab.

The algorithms were implemented using Java. Experiment was performed using initial training period from 10 epochs to 150 epochs for data accumulation process. This data is used for clustering the sensors based on data correlation in terms of magnitude similarities, trend similarities and geographical proximity of the sensors. Clusters of sensors formed using different initial period. Cluster of sensor with initial period of 120 epochs is depicted in Figure 5.

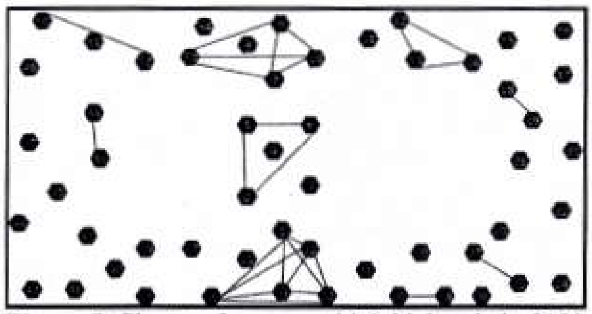

Figure 5: Cluster of sensors with initial period of 120 epochs

7. Energy Saving

Once, sensors are clustered based on data correlation, sink collects the remaining data using the EAEEDC framework. Energy saving is calculated by reductions in terms of total number of messages transmitted from the sensors to the sink using EAEEDC as compared to the total number of messages transmitted without clustering the sensors. Table I presents the energy saving (in %) using EAEEDC framework in comparison to situations where all sensors are actively used for sensing and transmitting. The above results clearly demonstrate the advantages of EAEEDC in terms of energy saving.

In the experiment we used magnitude similarity parameter $m = 50$, trend similarity parameter $t = 80\%$ and maximum distance *gmax_dist* = 10 meters during clustering as well as dynamic adjustment period.

TABLE 1:ENERGY SAVING USING EAEEDC

Initial Period (in Epochs)	*Energy Saving (in %)*
10	2.00
20	2.37
30	1.74
40	1.14
50	1.84
60	2.59
70	1.71
80	2.54
90	3.07
100	2.69
110	4.49
120	3.69
130	3.48
140	3.93
150	3.94

8. Conclusion

The existence of spatial and temporal correlations among the sensor observations are significant and unique characteristics of the WSN. In this paper, we introduced a framework to capture the spatial and temporal correlations in wireless sensor networks. Since the clustering and scheduling of the sensors are based on spatio-temporal correlations, it offers better accuracy as compared to the clustering of sensors based on network topology. At present comparison of correctness of data collected using EAEEDC and EEDC are being performed. In future, we plan to implement EAEEDC on multidimensional data.

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A comparative study on the effect of UV irradiation on selected bacterial species.

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Abstract

The presence of microorganisms like bacteria in nearly every part of the biosphere makes it a health hazard for humans and other animals alike. In order to prevent contamination from bacteria especially in food, water and medical supplies and equipment, it is necessary to either kill or remove them by using physical or chemicals agents. One of the most commonly used means of sterilization is exposure UV light. The use of UV radiation especially UV-C which has a wavelength range of around 200 nm causes mutations in bacterial DNA and this hampers the functionality of the cell and eventually leads to death. In this study, *Escherichia coli, Enterobacteraerogenes, Proteus vulgaris* and *Pseudomonas alcaligenes* were exposed to UV-C radiation to compare its effect on their growth and survival. It was found that *P. alcaligenes* was the most resistant to UV-C irradiation while *P. vulgaris* was the most susceptible. These results also showed that the use of only UV-C radiation as a means of sterilization may not be enough to remove or kill bacteria. Other means of sterilization may it be physical or chemical may therefore also be needed to be used side by side with UV radiation to enhance sterilization and thus prevent infection from bacterial contamination.

Keywords: *Ultraviolet, sterilization, resistance, contamination, mutation*

1. Introduction

The wide variety of microorganisms on this planet, especially bacteria, have adapted and evolved to survive in different environmental conditions. Of all the major factors that contribute to the survival of life on earth, sunlight and its diverse spectrum of wavelengths is one of the most important. Apart from being the ultimate source of energy for all life forms, its diverse wavelengths also produce varied effectson the biosphere.

Sunlight consists of the visible spectrum which provides life sustaining energy and enables vision and the extreme invisible spectra include the Ultra-violet (UV) spectrum and Infra red (IR) spectrum. These spectra of sunlight travel in the form of waves and have different wavelengths. UV light has wavelengths between 100 nm and 400 nm and is considered to be a non-ionizing radiation (Bassiri, n.d; Furlong, n.d). It is usually categorized as UV-A, UV-B and UV-C depending on the wavelengths. UV-C has the shortest wavelength and contains more energy

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than the former two. Still, all the three forms of UV light are being used regularly in hospitals and food industries as sterilizing agents to prevent microbial growth and even to kill them (Furlong, n.d; Vermeulen et. al., 2007). The germicidal action of UV can be attributed to its ability to generate free radicals and thymine dimers. Free radicals attack the DNA and proteins of bacteria and damage them thereby disabling their normal cellular function. Thymine dimers on the other hand constitute a form of mutation which would affect correct DNA replication and transcription and thus prove detrimental to the bacterial cell (Bassiri, n.d; Chudobova et. al., 2015; Szczawińskiet.al., 2011). The formation of thymine dimers is the most common effect of UV irradiation.

Inspite of harmful effects of UV light, several microbes are still able to survive UV irradiation. One of the mechanisms by which bacteria are able to survive is the presence of a DNA repair enzyme called photolyase which uses visible to blue light to remove thymine dimers and restore the damaged DNA lesion in a process called photoreactivation (Chudobova, et.al., 2015; Pierce, 2012; Worthington et. al., 2003). Another enzyme called superoxide dismutase removes free oxygen radicals (superoxide) generated by UV irradiation from the bacterial cell. Some researchers have also mentioned the role of the bacterial spore coat layers in providing protection against UV light (Myasnik et. al., 2001). Other parameters that play a role in the susceptibility or resistance of bacteria to UV light exposure include wavelength of the UV light and the exposure time (Vermeulen et. al., 2007).

In this study, four species of bacteria were exposed to UV light at different time intervals in order to compare their ability to survive UV irradiation. Three bacterial species used are commonly found members of the Enterobacteriaceae family which are usually found as contaminants of water and food while one species is a member of the Pseudomonadaceae family. The findings from this study have demonstrated that different microorganisms respond differently to UV irradiation based on the study parameters like wavelength and exposure time as reported by Bachem & Dushkin, 1932.

2.Materials and Methods

2.1. Preparation of Medium and Cultures

5 conical flasks (250 ml) containing 100 ml of Nutrient Broth (HiMedia, India) were sterilized and incubated at 37°C for 24 hours to check for contaminants. Four of the media containing flasks were inoculated with lyophilized cultures of *Escherichia coli* (MTCC-433), *Enterobacteraerogenes* (MTCC-2822), *Proteus vulgaris* (MTCC-426) and *Pseudomonas alcaligenes* (MTCC-493T)obtained from IMTECH, Chandigarh. The inoculated flasks were incubated at 37°C for 24 hours in a shaker incubator to revive the cultures.

13 Petri dishes containing sterile Nutrient agar (HiMedia, India) were also prepared and incubated for 24 hours at 37°C to check for contamination.

2.2. Spread Plating

4 (four) sterile Nutrient Agar plates were each labeled with the name of the test organism and the time of UV exposure in minutes (10, 20and 30) respectively. Duplicates of these plates were prepared. These plates were

then aseptically inoculated with the respective bacterial species respectively by spread plating using a sterile L – shaped spreader.

2.3. UV Exposure

The inoculated plates were uncovered and exposed for different time periods (10 mins, 20 mins, 30 mins and 40 mins) to UV-Cradiation using the UV lamp (Philips TUV 15W G15 T8 UVC) inside a shaker incubator (Rotek LIS, Pelican Instruments) as the source of UV light. During the whole period of exposure, the room was kept dark to avoid photoreactivation. After exposing the plates, they were taken out and incubated in a bacteriological incubator at 37°C for 24 hours. The uninoculated plate was used as a control and also incubated.

3. Results

The four different bacterial species used in this study showed varied responses to UV-C irradiation. The most resistant towards UV-C exposure was found to be*P.alcaligenes* which formed a continuous lawn over all the plates exposed at all the four different time periods. The next most resistant species was found to be *E. aerogenes* followed by *E. coli* while *P. vulgaris* formed scattered colonies over all the four plates. The test results also revealed that except for *P. alcaligenes*, the other bacterial species used showed a decrease in the population of bacterial cells growing in the plates as the exposure time increased. This can be observed by the level of clear zones or plaques being formed in the plates. In the case of *E. aerogenes*, there was a distinct clear zone of no bacterial growth in the plate exposed for 30 minutes while the plates exposed for 10 and 20 minutes showed no difference in the culture characteristics. *E. coli* showed larger plaque formation in the 20 minutes exposed plate as compared to the 10 minutes exposed plate .The 30 minute exposed plate however showed plaque formation to be more than the 10 minute exposed plate and less than the 20 minute exposed plate. With *P. vulgaris*, the level of plaque formation showed gradual increase with increase in the time of exposure.

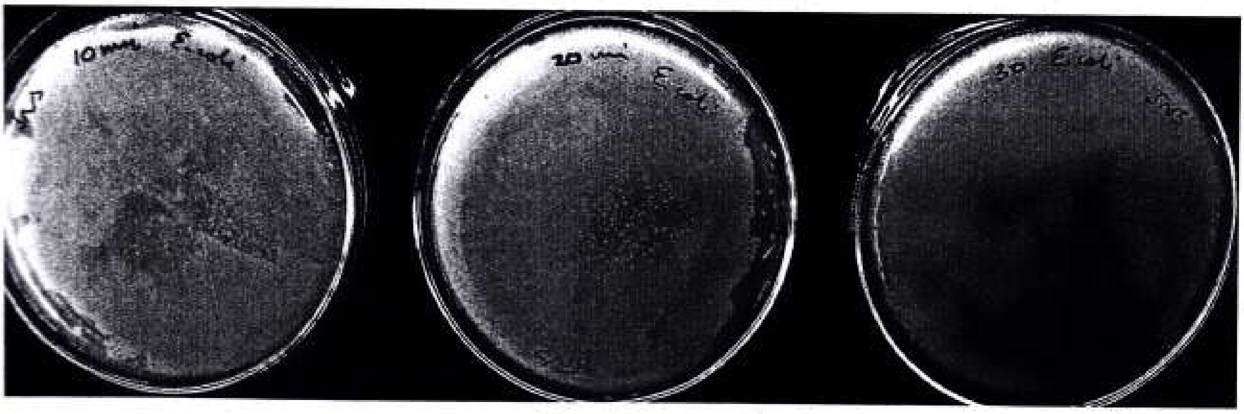

Fig. 3.1.*E. coli* cultures growing on nutrient agar plates after UV irradiation for ***a***. 10 mins, ***b***. 20 mins and ***c***. 40 mins. There is a slight effect of UV irradiation on the cultures but no distinguishable effect with increase in exposure time.

Fig. 3.2.*Enterobacteraerogenes* culture growing on nutrient agar plates after UV exposure for **a.** 10 mins, **b.** 20 mins and **c.** 30 mins. The arrow in **c.** indicates a clear zone of no bacterial growth.

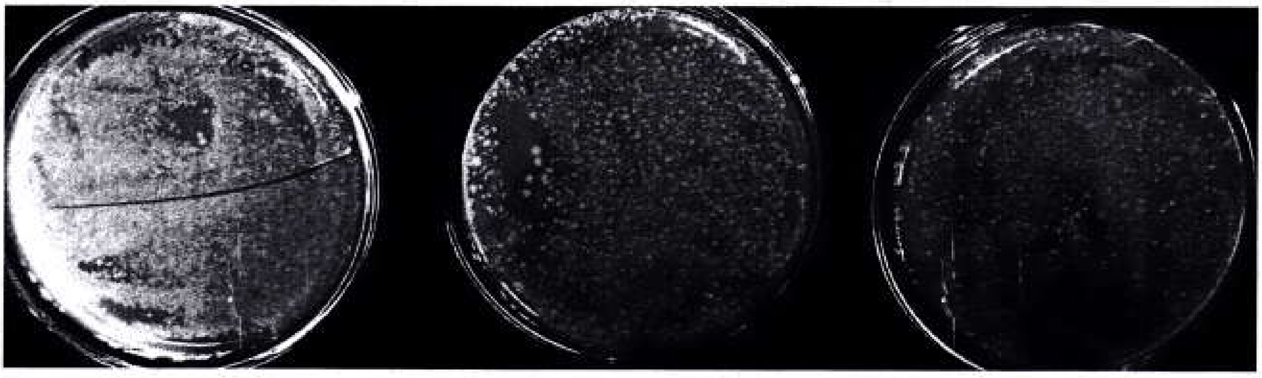

Fig. 3.3.*Proteus vulgaris* growing on nutrient agar plate after UV exposure for **a**. 10 mins, **b**. 20 mins and **c.** 30 mins. There is a distinct gradual decrease in the number of bacterial colonies as the exposure time increased.

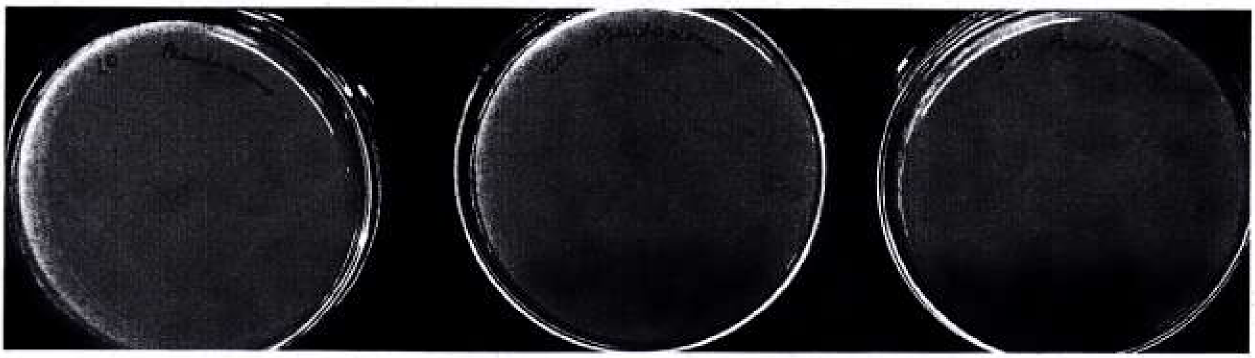

Fig. 3.4.*Pseudomonas alcaligenes* culture growing on nutrient agar plates after UV exposure for **a.** 10 mins, **b.** 20 mins and **c.** 30 mins. There is no observable effect of UV irradiation on the cultures with increase in time.

4. Discussion and Conclusion

The results obtained in this study showed the variability in the effect of UV radiation on four different bacterial species. This difference could be due to several factors in the bacterial cells like their structural make up or in their cellular enzymes. One of the reasons for the absence of complete germicidal effect in all the plates could be that the revived cultures in the broth had reached the stationary phase and had achieved a heightened repair system (Abedi-Moghaddam et al., 2004). The differences in the resistance against UV-C irradiation among the four bacterial species could be attributed to their cell wall components where the thicker cell wall containing bacterial species will have more resistance as reported by Arrage et al., 1993. Since none of the species used in this study are spore formers, their resistance or susceptibility could not be due to the presence or absence of spores (Myasnik et al., 2001).

In conclusion, this study has revealed that even though UV irradiation could be used as a means to achieve sterility and germicidal action (Kodoth& Jones, 2015), some bacterial species can still survive. Their ability to survive against the harshest of environmental conditions enables them to inhabit nearly every nook and corner of the earth. However, since most microbes are strict pathogens or opportunistic pathogens, it is imperative to use whatever means to kill or remove them. Along with UV irradiation which is mostly used in hospital and industrial settings, other means of sterilization should also be used side by side to achieve a more sterile condition. This will ensure a proper prevention from any type of bacterial contamination and thereby reduce the risks to human health.

Acknowledgement

The authors would like to thank the Department of Biotechnology (DBT), Govt. of India for sponsoring this study through its Star College Scheme. Thanks also go to Dr. H. G. Lyngdoh, Head, Department of Biochemistry, St. Anthony's College, Shillong for his support during the entire period of this study. Also, the authors extend sincere thanks to Ms. S. Lyndem, Asst. Professor, Dept. of Biotechnology, St. Anthony's College for her help during the study period.

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Phytochemical Analysis of the Crude Extracts of *Clerodendrumchinense*and *Mazuspumilus*

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Abstract

Phytochemical constituents of a plant contribute to its medicinal properties and other versatile applications. Hence, they are studied extensively for the discovery and development of leadmolecules with various applications. Medicinal properties and biological activities of a plant can be validated by detecting and studying the active components in the plant extracts. The present study focuses on analysis of the crude extracts of *Clerodendrumchinense* and *Mazuspumilus*for the presence or absence of different phytochemicals like alkaloids, flavonoids, terpenoids, tannins, glycosides, phenolics, coumarins, proteins, carbohydrates, saponins, vitamin C and amino acids. Both the samples were positive for the presence of most of the constituents mentioned above. There is a very strong presence offlavonoids, terpenoids and phenolics, and absence of saponins and alkaloids in *Mazuspumilus.* However, in*Clerodendrumchinense*, there is a strong presence ofproteins, carbohydrates and amino acids and absence of alkaloids.

Key words:Phytochemical constituents, *Clerodendrumchinense, Mazuspumilus,* Flavonoids, Phenolics, Terpenoids

1.Introduction

The history of the use of plants and plant based products as a source of medicine dates back to the middle Paleolithic age around 60,000years ago (Solecki&Shanidar, 1975).According to World Health Organization (WHO) almost 65% of the world's population depends on plants for their primary health care need and 25% of all drugs prescribed today are of plant origin(Mukhopadhyay*et al.,* 2012). The phytochemical constituentsof a plant contribute to its

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medicinal properties and other versatile applications.They are, therefore, studied extensively for the discovery and development of lead molecules with various applications (Mamta&Jyoti, 2012). It is in this direction that, the crude extracts of the leaves of *Clerodendrum*and whole plant of *Mazuspumilus* is analysed in the present study for thepresence or absence of different biologically active phytochemicals

The chemical constituents of a plant, based on their functional group, canbe broadly grouped as phenolics, flavonoids, alkaloids, tannins, glycosides, terpenoids and others (Shrivastava & Patel, 2007). Some features and biological activities of phytochemicals are listed in **Table 1**.

Clerodendrumchinense

The *Clerodendrumchinense* **(Figure 1)** is a perennial shrubnative to southern Asia. It belongs to *Clerodendrum*genus which falls under Verbenaceae family. The genus *Clerodendrum* contains many plant species well known for itsbiological activities and therapeutic value (John & Singha, 2014).People in many Asiancountries like India, China, Korea, Japan and Thailand have been using *Clerodendrumchinense*as traditional medicine for the treatment of fever, jaundice, typhoid, syphilis,rheumatism, asthma and other inflammatory diseases.Ethno-medical importance,isolation and identification studies of the chemical constituents of various species belonging to the genus *Clerodendrum,* has been reported. Phenolics, steroids, terpenoids, flavonoids, alkaloids and oilsare some of major groups of phytochemicals reported from this genus(Shrivastava & Patel, 2007). Reports on the bioactive compounds of *Clerodendrumchinense* are, however, not available.Hence, the phytochemical analysis of the leaves of the species *Clerodendrumchinense* may validate its potential as a medicinal plant.

Table 1: Structural features and activities of various phytochemicals from plants

Phytochemical	Structural features	Example(s)	Activities	References
Phenols and Polyphenols	C3 side chain, - OH groups, phenol ring	Catechol,Epicatechin, Cinnamic acid	Antimicrobial, Anthelmintic, Antidiarrhoeal, Aimutagenic,Anti-carcinogenic, Anti-platelet, Anti-inflammatory, Antioxidant	Li *et al.,* 2014; Mir *et al.,* 2013; Mukhopadhyay*et al.,* 2012;Tiwari*et al.*,2011;Shrivastava& Patel, 2007.
Flavonoids	Phenolic structure, one carbonyl group. Hydroxylated phenols, C6-C3 unit linked to an aromatic ring	Chrysin, Quercetin, Rutin	Antimicrobial, Anti-inflammatory, Anti-mutagenic, Antineoplatic, Anti-carcinogenic, Antiallergic, Anti-platelet,Anti-thrombotic and Vasodilatory	Kumar & Pandey, 2013;Mir *et al.,* 2013;Mukhopadhyay *et al.*,2012;Tiwari*et al.*,2011;Shrivastava& Patel, 2007.
Tannins	Polymeric phenols (Mol. Wt. 500-3000)	Ellagitannin, Acertannin	Antihelmintic, Antitumor, Antimicrobial, Anticancer	Mukhopadhyay *et al.*,2012;Tiwari*et al.*,2011; Okuda & Ito, 2011.
Coumarins	Phenols made of fused benzene and α-pyrone rings	Warfarin, Conferol, Aurapten, Esculetin	Antiviral, Antitumor, Anti-HIV, Anticoagulant, Anti-inflammatory	Mukhopadhyay *et al.*,2012;Tiwari*et al.*,2011.
Terpenoids and essential oils	Acetate units + fatty acids, extensive branching and cyclized	Capsaicin, β-caryophyllene, kaurenoic acid, copalic acid, polyalthic acid	Anthelmintic, Antidiarrhoeal,Antitumor,Anti-inflammatory,cytotoxicity,Antimicrobial	Leandro*et al.,* 2012; Mukhopadhyay*et al.*,2012; Shrivastava& Patel, 2007;Tiwari*et al.*,2011.
Alkaloids	Heterocyclic nitrogen compounds	Berberine, Piperine, Palmatine, Tetrahydropalmatine	Antimicrobial,Anthelmintic, Antidiarrhoeal, Anticancerous	Mir *et al.,* 2013; Mukhopadhyay*et al.,* 2012; Shrivastava& Patel, 2007; Souto*et al.*, 2011; Tiwari*et al.*, 2011.
Polypeptides and Lectins	Proteins	Mannose-specific agglutinin, Fabatin	Antimicrobial, Anthelmintic	Tiwari*et al.*, 2011.
Glycosides	Sugar + non carbohydrate moiety	Amygdalin, Calcealorioside	Antidiarrhoeal, Antioxidant, Immunomodulatory, Anti-inflammatory, Neuroprotective	Mukhopadhyay*et al.,* 2012; Shrivastava& Patel, 2007; Tiwari*et al.*, 2011.
Saponins	Amphipathic glycosides	Vina-ginsenosides-R5 and -R6	Antidiarrhoeal, Anticancer,Anthelmintic, Hypolipidaemic activity, Hypoglycemic activity, Hepatoprotective, Antiulcerogenic, Immunomodulatory	Kharkwal*et al.,* 2012; Mukhopadhyay*et al.,* 2012; Shrivastava& Patel, 2007; Tiwari*et al.*, 2011.

ISSN 2349 2937

Mazuspumilus

Mazuspumilus (**Figure 2**)is an annual herb belonging to the family Scrophulariaceae. Plants belonging the genus *Mazus* are reported to be used in traditional medicine as an aperients, emmenagogue, febrifuge, for the treatment of some infections and as a tonic.The juice of *Mazuspumilus*is used traditionally for the treatment of typhoid.It is reported to have antioxidant, antimicrobial and cytotoxic activity (Riaz*etal.,* 2012;Shahid*et al.*, 2013).*Mazuspumilus* is also used by Khasi tribes of Meghalaya, as a medicinal herb for healing wounds and inflammation. Plants under the *Mazus* genus are reported to have phytochemicals like flavonoids, saponins, tannins, steroids, alkaloids and terpenoids (Riaz*et al.,* 2012; Farooq, 2013). Therefore, the present analysis may help in understanding the medicinal potential of the plant.

Figure 1.*Clerodendrumchinense.*The inflorescence and part of the plant.

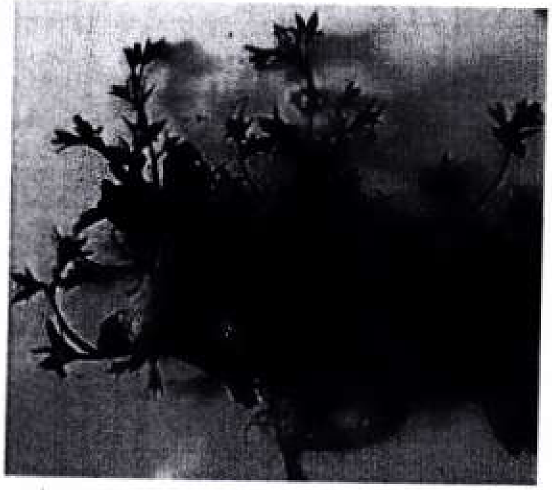

Figure 2.*Mazuspumilus.*The whole plant.

2. Materials and Methods

2.1. Collection and Preparation of Plant Samples

Leaves of *Clerodendrumchinense* and whole plantof *Mazuspumilus* were collected during June and July from Diengpasoh village, East Khasi Hill district of Meghalaya, India. It was further identified by Botanical Survey of India, Shillong, Meghalaya. The plant samples were thoroughly washed with waterand excess water drained off by drying it on a filter paper at room temperature. The fresh samples were then ground with distilled water in a mixer grinder,filtered through a muslin cloth and the filtrate obtained was used for further analysis.

2.2. Phytochemical Screening

The phytochemical tests were carried out using standard procedures to identify the components (Bhandary *et al.*, 2012; Mamta & Jyoti, 2012; Tiwari *et al.*, 2011)

Test for Flavonoids

a) Alkaline Reagent Test -Test solution when treated with sodium hydroxide solution, shows increase in the intensity of yellow color which would become colorless on addition of few drops of dilute Hydrochloric acid, indicating the presence of flavonoids
b) Ferric chloride test - Test solution when treated with few drops of Ferric chloride solution would result in the formation of blackish red color,demonstrating the presence of flavonoids.

Test for Alkaloids

a) Wagner's Test- Test solution when treated with Wagner's reagent(Iodine in Potassium Iodide) would result in the formation of reddish-brown precipitate. The formation of the reddish-brown precipitate confirmsthe presence of alkaloids
b) Hager's Test– Test solution when treated with few drops of Hager's reagent (saturated picric acid solution) would result in the formation of yellow precipitate, indicating the presence of alkaloids.

Test for Phenolics

a) Ferric Chloride Test-Test solution when treated with 3-4 drops of ferric chloride solution would result in the formation of bluish black color,demonstrating the presence of phenolics.

Test for Proteins

a) Millions Test- Test solution when treated with 2ml of Million's reagent would result in the formation of whiteprecipitate, indicative of the presence of proteins.

Test for Amino Acids

a) Ninhydrin Test - Test solution when boiled with 4% solution of Ninhydrin, would result in the formation of purple color, confirming the presence of free amino acids.

Test for carbohydrates

a) Fehling's Test- Test solution when boiled with Fehling's solution would result in the formation of brick red precipitate which confirms the presence of carbohydrates.

Test for Saponins

a) Foam Test - Test solution whenmixed with water and shaken would result in the formation of froth, which is stable for 15 minutes,indicating the presence of saponins.

Test for Tannins

a) Ferric Chloride Test- Test solution when treated with 3-4 drops of ferric chloride solution would result in the formation of transient greenish to black colour, confirming the presence of tannins.

Test for Glycosides

a) Keller Killiani Test - Test solution when treated with few drops of glacial acetic acid and Ferric chloride solution and mixed, followed by the addition of concentrated sulphuric acid resulted in the formation of two layers. Lower reddish brown layer and upper acetic acid layer which turn bluish green, indicating the presence glycosides.

Test for Terpenoids

a) Salkowski's Test-Test solution when treated with chloroform and a few drops of concentrated sulphuric acid, mixed and allowed to stand would result in the formation of golden yellow colour, demonstrating the presence of triterpenes.

b) Copper acetate Test- Test solutionwhen diluted with water and treated with 3-4 drops of copper acetate solution would result in the formation of emerald green colour which confirms the presence of diterpenes

Test for Resins

a) Test solution when treated4% HClwould result in theappearance of turbidity, indicating the presence of resins.

Test for coumarins

a) Test solution was taken in a test tube, covered with a filter papersaturated in NaOH and then boiled in a water-bath for 10 minutes. The filter paper was then exposed to UV light. The presence of coumarin is indicated by a green bright yellow color.

Test for Vitamin C

a) DNPH Test- Test solution when treated with Dinitrophenyl hydrazine dissolved in concentrated sulphuric acid would result in the formation of yellow precipitate, confirmingthe presence of vitamin C.

3. Results and Discussion

The present study carried out on the plant samples revealed the presence of biologically active constituents, like flavonoids, terpenoids, tannins, glycosides, phenolics, coumarins, proteins, carbohydrates, vitamin c and amino acids in both the plant samples. Whereas, saponins were detected only in *Clerodendrumchinense* and alkaloids was absent in both the samples (**Table 2**).

Table 2. Phytochemical constituents of *Clerodendrumchinense* and *Mazuspumilus*

Serial No.	Phytochemical constituents and Test(s) performed	*Clerodendrumchinense*	*Mazuspumilus*
1	**Flavonoids** a)Alkaline Reagent Test b) Ferric Chloride Test	 + +	 ++ +
2	**Alkaloids** a)Wagner's Test b) Hager's Test	 _ _	 _ _
3	**Phenolic Compounds** a) Ferric Chloride Test	 +	 ++
4	**Proteins** a) Millions Test	 +	 +
5	**Amino Acids** a) Ninhydrin Test	 ++	 ++
6	**Carbohydrates** a) Fehling's Test	 ++	 ++
7	**Saponins** a) Foam Test	 +	 _
8	**Tannins** a) Ferric Chloride Test	 +	 +
9	**Glycosides** a) Keller Killiani Test	 +	 ++
10	**Terpenoids** a)Salkowski's Test b) Copper Acetate Test	 + +	 ++ ++
11	**Resins**	+	+
12	**Coumarins**	+	+
13	**Vitamin C**	+	+

Key: + + = Strong Presence, + = Weak Presence, - = Absence

Phytochemical analysis suggests that biological activities and the traditional uses of the plant samples under study could be because of the presenceof phytochemical constituentswith wide therapeutic value in the plants(**Table 1**).Plants belonging to the genus *Mazus*are reported to have very good antioxidant, antimicrobial and cytotoxic activity. Strong presence offlavonoids, terpenoids, and phenolicsin *Mazuspumilus* may account for its reportedantioxidant and cytotoxic activity, further phytochemical investigationsmay bring to light the bioactive potential of this plant.

It is pertinent to mention that the present study on*Clerodendrumchinense* correlates with reports on the phytochemistry of *Clerodendrum* genus. *Clerodendrum* genus is well known for the presence several bioactive phenolics, flavanoids, terpenoids and steroids with multiple biological activities.However estimationof the bioactive constituents found in the present study is necessary to validate the same.

In conclusion, further studies on the phytochemistry of both the plant samples may help to confirm and explore the traditional and therapeutic value of the plants.

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Adoption of Scientific Fish Farming by the Fish farmers of Meghalaya

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Abstract

The present study was carried out to assess the adoption level of scientific fish farming in Meghalaya. Overall mean adoption of twelve practices of scientific fish farming indicates low level of adoption with score 3.8 ± 1.6. It was observed that education, age and farm size had positive and significant relationship with adoption of scientific fish farming. The average fish production in the study area was estimated as 769 kg/ha/year. The main reason of low adoption of scientific fish farming technology by the farmers in the study area is due to lack of knowledge on scientific fish farming. The technology constraint, that needs to be addressed in order to popularize scientific farming at farmer level. Organizing training and demonstration programmes on scientific fish farming at field level for farmers is utmost important to increase fish production in the state.

1. Introduction:

Freshwater aquaculture in India is the major contributor to the fish basket where its share has increased from 46% in 1980s to over 85% in the recent years. It has increased ten-fold from 0.37 million t in 1980 to about 4.03 million t in 2010 with a mean annual growth of about 6%.Development of induced breeding technique of Indian Major Carps in the 1957 and subsequently launching of The All India Coordinated Research Projects in 1971to standardize composite fish culture technology in active partnership with various State Governments which has practically revolutionised the aquaculture sector in the country. The average national production from the ponds has increased from 600 kg/ha/year in 1974 to 2900 kg/ha/year in recent time with a number of farmers even demonstrating production levels as high as 8000–12000 kg/ha/year(Anon, 2013). The Indian Upland states including Meghalaya, extending from North western to North-eastern holding fishery of cold waters and sub temperate species, contribute nearly 3-4% to the total fish production basket. Indigenous people of the North Eastern Region of the country are mostly fish eaters butthis regionis importing fish from other states of India particularly from Andhra Pradesh to meet the present demand of the fish. (Mohan, 2012).Aquaculture is one of the important enterprises in the state of Meghalaya and the rural farmers have at least one or two ponds within their farm area for fish culture (Bujarbaruah,1996).The Average fish production of FFDA adopted ponds of Meghalaya has recorded 1500 kg/ha and with 8300 ha area under FFDA the potential fish production of the state is 12.45 thousand t. But till 2013 fish production was recorded only 5890 t which include the Indian Major Carps, medium carps namely *Labeogonius, L calbasu*, minor carps *Cirrhinusreba, L bata* and Exotic carps. Carp is the most important group in aquaculture in Meghalaya, its production in Meghalaya has shown a increasing trend with a major/minor carp production 1896 t and exotic carp 1027 t in 2007 to 2551t major/minor carp and 1851 t exotic carp (Hand book of fisheries statistics,2014). Integrated fish farming fits in the hilly area and integratedaquaculture strategies are regarded as an efficient utilization of available resources, waste recycling and energy saving, and for maintaining ecological balance in sub tropical hill agro ecosystem (Kumaresan*et al*, 2008).Dwivedi, *et al*, 1983, stated that the major components of any aquaculture system are development of aquaculture technology, technology transfer, funding aquaculture projects, production and post harvest technology. The present study was conducted with the following objectives (i) to study the adoption level of scientific fish farming in Meghalaya (ii) to study selected socio-demographic characteristics of the respondents (iii) to assess the constraints in adoption of scientific fish farming in the state.

2. Methodology

The study was conducted during the year 2013-2015 in the eight blocks *viz.* Mairang, Mawthadraishan, Umsning and Umling block, Shella- Bholagang block of Khasi hills and Resubelpara and Tikrikilla and Selsella block of Garo hills. Data wascollected from 120 fish farmers from eight blocks by distributing questionnaires. Five selected characteristics viz. Gender, caste, age, education and the size of the fish farmof the respondents were measured and categorised by following standard methodology used by Lyngwa et al, 2015, Ramakrishna et al, 2013. The standardised summated scale technique was employed in the present study for measuring knowledge score of respondents about package of practices of scientific fish culture. Scientific fish farming which consists of twelve practices*viz.* (i) pond preparation (ii) stocking time (iii) stocking of fingerling, (iv) stocking density (v) maintaining stocking ratio (vi) application of lime (vii) application of fertilizer (viii) providing feed to fish (ix) monitoring water quality (x) monitoring fish health (xi) keeping record (xii) proper marketing.Adoption of practice was given 1 point and non adoption 0. Adoption score was calculated to categorize respondents into three groups, viz. Low, medium and high adoption levels. The low level of adoption score range is 0 to 4 (0 -33.3%), medium adoption with score 4.01 to 8 (33.4 to 66.6%), high adoption with scoring from 8.01 to 12 (66.7 to 100%) as per methodology of Bhaumik et al. (1992) with slight modification.

Equation to calculate adoption% is given below.

$$\text{Adoption (\%)} = \frac{\text{Total obtainable Score}}{\text{Maximum obtainable score}} \times 100$$

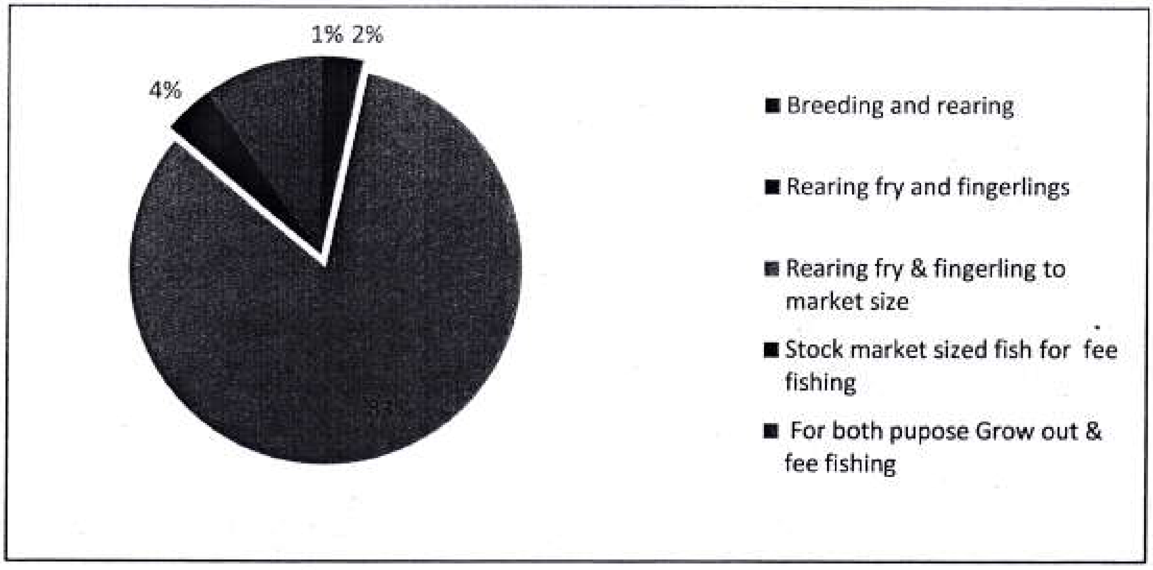
3. Results and discussion

Findings contained in Table 1 on socio-demographic characteristics of the respondents indicate that 63% (75) of the respondents were male and 37% (45) were female. 100% respondents were belonging to schedule tribe.On assessment of the educational status of fish farmers shows that there was no illiterate fish farmer in the study area. 17% farmers were educated at primary school level, 50% secondary level and 33% farmers were above secondary level. A large number of fish farmers belonged to the educated class from IV to X. Majority of the fish farmers (58%) were belong to adult group, followed by young adult (34%) and young age (8%).This result is in conformity with Anon, 2013. Farm size of the farmers constitute mainly of three categories very small (27%), small (65.5%) and medium (6.5%) sized fish farm. Majority of the farmers have small sized fish farm with an area of 0.06 ha to less than 1 hectare followed by very small farm within the range of 0.01 to 0.05 ha. Only 6.5% farmer have the medium sized fish farm within range of 1 to 2 hectare.Majority of fish farmer (82%) were rear the fish up to table size. About 9% of the farmers culture fishes and alsoallow anglers for fee fishing. 4% farmers wereraising fish only for fee fishing not to sale. 2% of the farmers supply fry and fingerlings and only 1%of the fish farmersrear fish for breeding purposes. On assessment of adoption level of scientific fish farming by farmers in study area, it was revealed that 96% of the fish farmers were observed to be in the low adoption category and 4% were under medium level of adoption. There was no farmer found with high level of adoption.Fish production per hectare per year was recorded during the study period block wise average fish production. It was noticed that fish production ranged from 450 to 1000 kg/ha/year with an average production 769 kg/ha/year.

Though fishing is an age old tradition in Meghalaya, but history of aquaculture is comparatively new in the state. It was observed that rural people of the state have started to accept aquaculture as means of a livelihood security. Earthen pond is the dominant aquaculture facilities in the state. Study on the profile of the farmers with regard to their socio economic status indicating many factors which can contribute in the present development of aquaculture and inthe near future. It was seen that 100 % of the farmers belonged to Schedule Tribes. The main ethnic tribes involved in fish farming were Khasi, Garo and Jaintia. Unlike Assam, there is no caste bar observed in fisheries business in the state. Farmers involve themselves in culturing, harvesting and selling the fish. It was seen that 39% of the fish farmer were female playing an important role in fish production. It was noticed that with regard to educational status 100% fish farmers were literate which implies that farmers were educated and education is an important factor, which has bearing with understanding and adopting the scientific fish farming technologies by fish farmers. Majority of the fish farmers (58%) observed were adult within the age range from 46 to 55 years age group followed by 34% fish farmers were within the range of 25 to 45 years. This indicates more involvement of the adult age group of people in fish farming.Results indicate that characteristics of respondents' viz. Education, age and farm size had positive and significant relationship with adoption of scientific fish farming. Similar observation was made by Sakib*et al* (2014) and Singh *et al* (2011).

The main reasonof low adoption of scientific fish farming technology by the farmers in the study area is lack of knowledge on scientific fish farming. Farmers do not have proper knowledge on scientific fish farming. It was observed that not a single farmer followed the five important practices of scientific fish farming namely releasing fish seed at the right time, maintaining proper stocking density and species ratio, monitor water quality of the fish pond and checking growth and health. Partial adoption forimportant practices like feeding, liming, was recorded. This is aclear indication that low adoption of scientific fish farming among fish farmers is the main reason of low fish production in the state. Another factor affecting in the growth of aquaculture is the small size of fish farm holding. It was observed that 27% of the fish farm was very small in size within the range of 0.01 ha to .05 ha and 65.5 % were small in size i.e 0.06 ha to less than 1 ha. Only 8.5% farms were medium in size i.e 1 to 2 ha in size. There was no farm recorded under moderately large and large farm category in the study area. The pond area is an important factor of fish production as it provides living space for fishes. The average fish production in the study area was calculated as 769 kg/ha/year which is lower than FFDA adopted ponds i.e. 1500 kg/ha/year (Anon, 2012).The constraint for high adoption of scientific fish culture in Meghalaya is basically due to inaccessibility to technology. Training and demonstration are the most important critical inputs in this regard. The technology constraint, that needs to be addressed in order to popularize scientific farming at farmer level. Organizing need based training and demonstration programmes on composite and integrated aquaculture system at field level for farmers is utmost important. It was observed that though technologies are available at the research station but the extension machinery in the state should emphasized on extending their scientific knowhow to the fish farmers through different programmes such as training, field demonstration to motive fish farmers to adopt scientific fish farming.

Fig 1: Kind of Fish farm operation in the study area



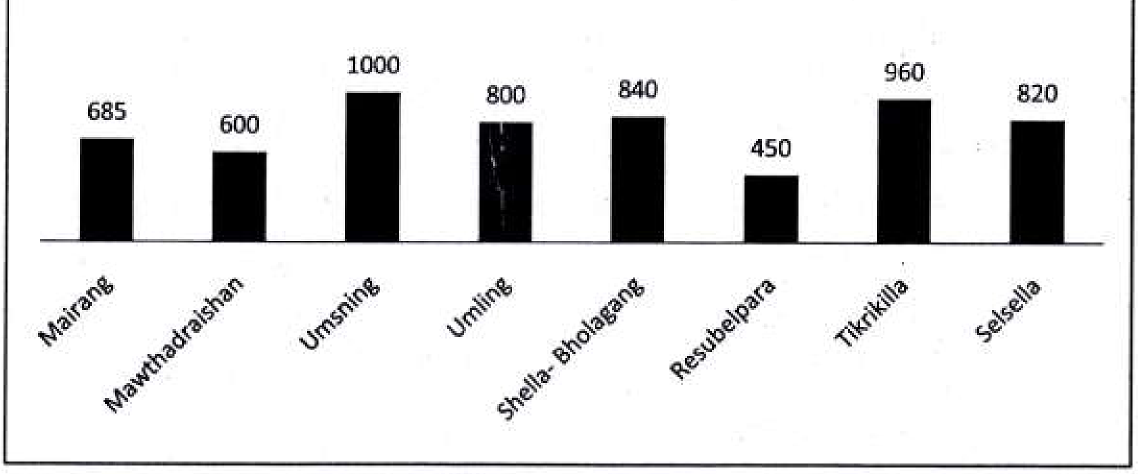


Fig 1: Block wise Average fish production in kg/ha

Characteristics	Categories	Respondents		Mean± SD
Gender		No	%	
	Male	75	63	-
	Female	45	37	
Caste				
	Schedule Tribe	120	100	
	Schedule Caste	-	-	
	Others			
Education	Illiterate	-	-	6.2 ±2.9
	Primary school (I-V)	20	17	
	Secondary School (VI-X)	60	50	
	Above Secondary (XI-Post graduate)	40	33	
Age	Young (25-35)	9	8	45±6.6
	Young adult (36-45)	41	34	
	Adult (46-55)	70	58	
	Old(Above 55)	-	-	
Fish farm size	Very small (0.01 - .05)	34	28	0.28±.02
	Small (0.06 to <1 ha)	80	67	
	Medium (1-2 ha)	6	5	
	Moderately large (2.1-5 ha)	-	-	
	Large (>5 ha)	-	-	

Table 1: Salient feature of the selected socio-demographic characteristics of the respondents

Table 2: Distribution of the Respondents according to their overall mean adoption of scientific fish farming

Adoption score &Percent	Adoption level	Farmer		Mean ± SD &Percent
		Number	Percent	
Up to 4 (Up to -33.3%)	Low	105	96%	3.8±1.6 (32%)
5- 8 (33.4 to 66.6%)	Medium	15	4%	
Above 8 (66.6% and above)	High	-	-	- .

Table 3: Relationship between the Selected Characteristics of Respondents and their Adoption of Scientific Fish Farming Practices

Independent variable	Coefficient of correlation(r)	Dependent variable
Education	0.25*	Adoption of Scientific fish farming
Age	0.76*	
Farm size	0.48*	

*= Significant at 5% level of significance

Acknowledgement: Authors are grateful to all fishers of the state who extended help in collection of data in preparation of the research paper.

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A note on *Humeranahumeralis* Boulenger, 1887 (Amphibia: Anura: Ranidae) from Arunachal Pradesh

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Abstract:

Ranid frog, *Humeranahumeralis* is known from Assam, Nagaland, Manipur and Arunachal Pradesh in Northeast India. In Arunachal Pradesh, this species is previously known from the eastern and the western parts with specific locality records. This paper deals with the first report from the central part of Arunachal Pradesh, with a note on the previous confirmed locality records from the State. The significance of locality records of any species lies in the fact that it plays a vital role in the field of taxonomy which gives a better understanding on the occurrence as well as the population trends of a species.

Keywords: Taxonomy, amphibians, Ranid frog, new locality, distribution.

Introduction

Theanuran species, *Humerana humeralis* was described from Myanmar (Upper Burma) by Boulenger (1887). Since then, the species is known to exist in Nepal, India and Bangladesh (Frost, 2017). In India; Ao, Bordoloi and Ohler (2003) reported this species for the first time from Nagaland. Subsequently, Mathew and Sen (2006) and Hussain *et. al* (2007) reported it from Assam and Arunachal Pradesh. Ningombam & Bordoloi (2007) reported the occurrence of this species from Loktak Lake, Manipur. Subsequent reports of *Humerana humeralis*from other localities of Northeast India are by Sen and Mathew (2008) and Humtsoe and Bordoloi (2014); [both from Nagaland], Das *et al* (2009) [from Assam] and Tesia and Bordoloi (2013) [from

Arunachal Pradesh]. Together these give this species a wide range of occurrence in four states of the region (*see***Table.1**). However, despite the occurrence of this species across various localities in Assam, this species is rarely encountered in the field in the rest of the three states. From Arunachal Pradesh, this species is known previously from three localities only.

In Arunachal Pradesh, *Humerana humeralis* is known to occur in Namsai.(Mathew & Sen, 2006) and Khonsa (Tesia & Bordoloi, 2013) from the eastern part of the State and Pakke Wildlife Sanctuary (Hussain *et. al.*, 2007) from the western part of the state. In this paper, we are reporting a new locality record from the central-west part of the state.

A single specimen of *Humerana humeralis* was collected from Yazali area in the Lower Subansiri District of Arunachal Pradesh [N 27° 23.319′, E 93° 45.084′, 615 m] by one of the authors (PN) in 2017, making this place the fourth locality record of this speciesin Arunachal Pradesh.

Materials And Method

A single specimen of *Humerana humeralis* was collected from Yazali, Lower Subansiri district, Arunachal Pradesh in 2017 by Dr. Prasanta Nanda and deposited in the National Zoological Collection of Zoological Survey of India, Shillong [Regd. No. V/A/NERC/1305]. The specimen is preserved in 8% formaldehyde solution. All measurements (in millimeters) were done with a Mitutoyo™digital caliper. The measurements used are SVL (Snout Vent length), HL (Head Length), HW (Head Width), MN (Mandible Nostril distance), MFE (Distance of mandible to the front of eye), MBE (Distance of mandible to the back of eye), IFE (Distance between the front of eyes), IBE (Distance between the back of eyes), IN (inter-narial distance), EN (Distance from eye to nostril), SN (Distance from snout tip to nostril), EL (Eye length), SL (Snout length), TYD

(Greatest Tympanum Diameter), TYE (Distance between tympanum and back of eye), IUE (Minimum distance between the upper eyelids), UEW (maximum width of the upper eyelid), HAL (Hand length), FLL (Forearm Length), TFL (Third finger length from the first subarticular tubercle to tip of the finger), FL (Femur Length), TL (Tibia Length), TFOL (Length of tarsus & foot), FOL (Foot length, from inner metatarsal tubercle to the tip of fourth toe), FTL (Fourth toe length, from first subarticular tubercle to the tip), IMT (Inner Meta-tarsal tubercle), ITL (inner toe length), MTTF (Distance from the distal edge of the IMT to the maximum incurvation of the web between third and fourth toes), TFTF (Distance between the maximum incurvation of the web between third and fourth toes to the fourth toe tip), MTFF (Distance from the distal edge of IMT to the maximum incurvation of the web between the fourth& fifth toes), FFTF (Distance between the maximum incurvation of the web between the fourth & fifth toes to the fourth toe tip).

Result

A medium sized, male frog (SVL-63.21 mm); snout pointed and projecting beyond mouth, head almost as broad as long, nostril nearer to snout tip. Upper lip whitish. Vomerine teeth present. A pair of external vocal sacs. The tympanum is round and about 3/4th the eye diameter. Presence of a pair of rectal glands behind the mandible. Another gland; humeral gland, is present at the base of the forearm. Fingers free; relative finger length are 2<1<4<3; fingers ending into disc of triangular shape. Toes fully webbed except the 2 phalanges on the 4th toe. Inner meta-tarsal tubercle present; outer absent. Tibio-tarsal articulation reaches the nostrils.

Dorsum smooth, slate coloured in preserved condition;olive brown in live condition, with black spots on the dorsum and thighs. Narrow dorso-lateral folds present. Ventrum is smooth. Morphometic readings of the specimen are also provided (*See* **Table. 2**).

TABLES

Table 1: Reported localities of *Humeranahumeralis* from India

Reported by	**State**	**Locality**
Ao*et. al.* (2003)	Nagaland	Tsurung
Mathew &Sen (2006)	Assam	Nameri, Sonitpur District
-Do-	Arunachal Pradesh	Namsai, Lohit District
Hussain*et. al* (2007)	Assam	13 localities across the State
-Do-	Arunachal Pradesh	Pakke Wildlife Sanctuary
Ningombam&Bordoloi (2007)	Manipur	Loktak Lake
Sen& Mathew (2008)	Nagaland	Tiru River, Mon District
Das *et. al.* (2009)	Assam	Barail WLS, Cachar District
Tesia&Bordoloi (2013)	Arunachal Pradesh	Khonsa, Tirap District
Humtsoe&Bordoloi (2014)	Nagaland	Wokha District
This paper (2017)	Arunachal Pradesh	Yazali, Lower Subansiri District

Table. 2: Morphometrics of the specimen collected from Yazali, Arunachal Pradesh

Sl. No.	Characters	In mm	Sl. No.	Characters	In mm
1	SVL	63.21	16	IUE	4.77
2	HL	19.82	17	UEW	5.28
3	HW	21.1	18	HAL	16.72
4	MN	15.07	19	FLL	11.57
5	MFE	9.5	20	TFL	9.0
6	MBE	5.95	21	FL	31.43
7	IFE	11.58	22	TL	34.20
8	IBE	15.68	23	FOL	30.65
9	IN	6.68	24	FTL	18.45
10	EN	6.15	25	IMT	2.72
11	EL	7.82	26	ITL	7.8
12	SN	4.88	27	MTTF	17.23
13	SL	10.85	28	TFTF	13.62
14	TYD	4.96	29	MTFF	21.09
15	TYE	1.63	30	FFTF	12.89

FIGURES:

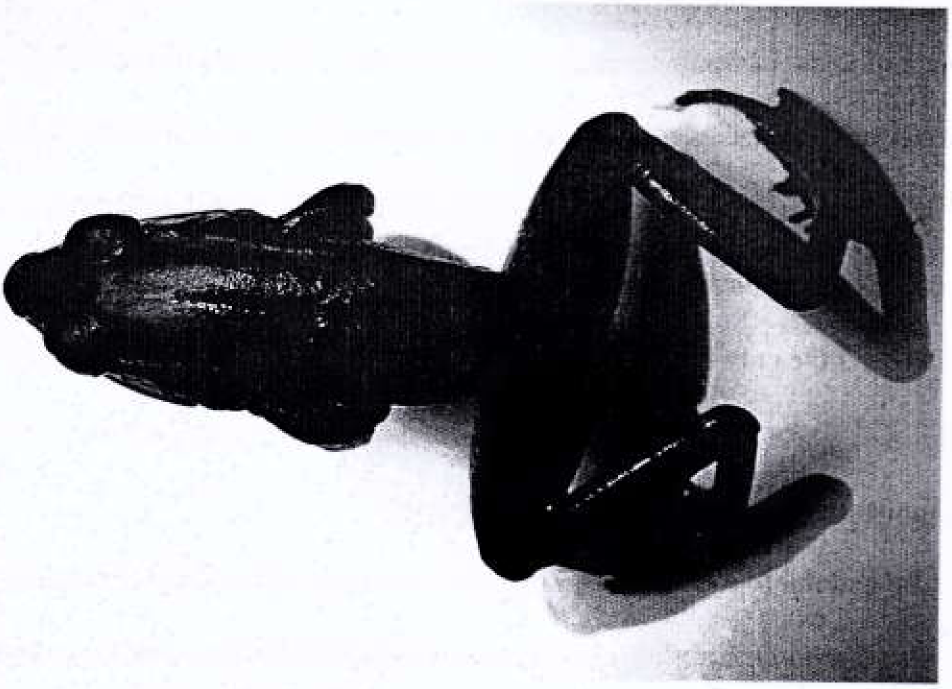

Fig. 1: The dorsal view of *Humeranahumeralis*from Yazali, Arunachal Pradesh

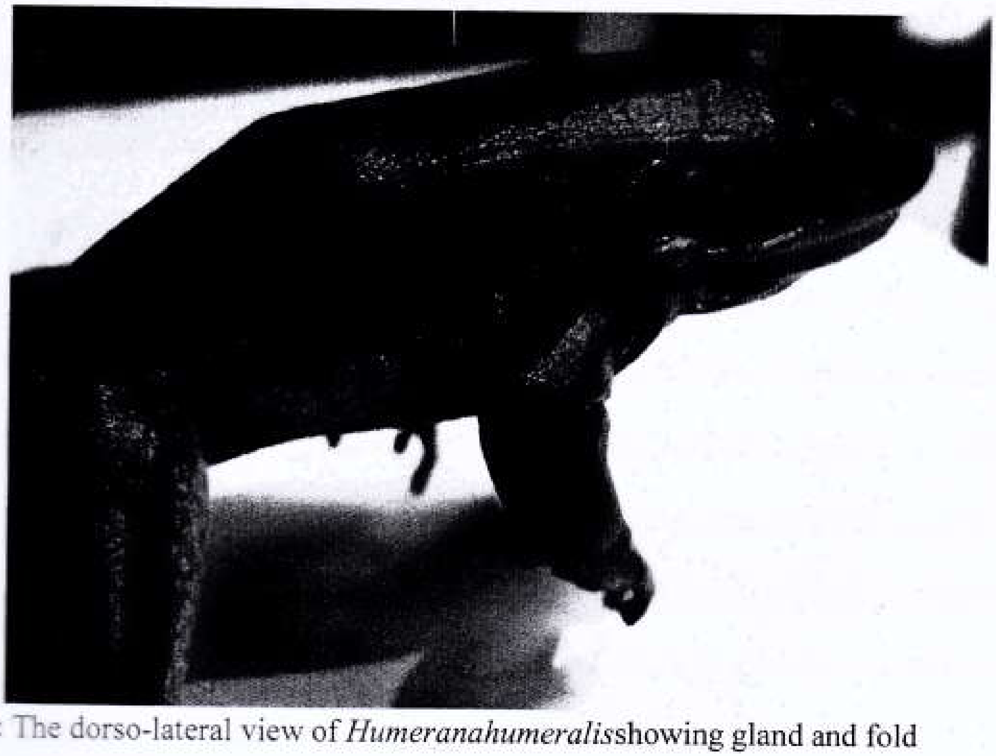

Fig.2: The dorso-lateral view of *Humeranahumeralis*showing gland and fold

Discussion

The wider occurrence of this species in the Northeast India and its surrounding countries justifies the assignment of Least Concern category in the IUCN red list data (van Dijk, 2004). Addition of locality records of any species plays a vital role in the field of taxonomy which gives a better understanding on the occurrence as well as the population trends of a species. In this regard, this locality report of *Humerana humeralis* from the central-west of Arunachal Pradesh is significant, which also makes it the only fourth record so far from the State.

Acknowledgements

The authors are grateful to the Director, Zoological Survey of India (ZSI) for providing facilities. Thanks are also due to Dr.Kaushik Deuti, Scientist, ZSI, Kolkata for confirming the identity of the specimen.

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Hydrogeochemical Analysis of Groundwater in Shillong City, Meghalaya

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Abstract

Shillong city has been exclusively relying on surface water sources namely, rivers and springs, but during recent years it has started using groundwater to meet the requirements of growing population. Hydrogeochemical investigation was carried out on shallow groundwaterto assess its suitability for drinking purpose. The analytical results present the abundance of the major ions in the following order: Mg >Ca> Na > K = HCO_3>Cl> CO_3 > SO_4>NO_3.Bicarbonate is the dominant anion found in the groundwater of the study area. The analytical result from the Piper trilinear diagram shows that there is a mixture of three types of water with variable concentrations of major ions. Ca-Mg-Cl-SO_4 type dominates with 50 % of the groundwater samples, around 35% falls under the Ca-Mg-HCO_3 type and the remaining 15% is of Na+K-Cl-SO_4 type. The third water type indicates a relatively high content of sodium suggesting a natural softening through base exchange has taken place. Piper trilinear diagram also reveals that the alkaline earth metals (Ca^{2+}, Mg^{2+}) are dominant over the alkalis (Na^+, K^+), and the strong acidic anions (Cl^-, SO_4^{2-}) exceeds weak acidic anions (CO_3^{2-}, HCO_3^-). Schoeller indices values shows 99% of the wells indicates chloro-alkaline equilibrium. Water quality index rating calculated reveals that groundwater in the study area are of excellent to unsuitable for drinking purposes.

Keywords: Shillong city, Hydrogeochemical, Piper trilinear diagram, WQI.

Introduction

Water is not only the essence of life but also one of the most crucial factors determining the quality of life of the people (Hwang et al, 2017). Climate change and increasing disruptions in the rainfall patterns, temperature and soil moisture have a direct impact onthe water availability and its suitability for drinking, livestock use, agriculture and various other purposes. In this respect, the latest patterns of climate change and water deficit reflect depletion of water sources and deterioration of water quality in many parts of the world (Raju et al., 2011; Raju et al., 2014 ; Toumi 2015).Water quality gets modified in the course of movement of water through the hydrological cycle and through the operation of processeslikeevaporation, transpiration, selective uptake by vegetation, oxidation/reduction, cation exchange, dissociation of minerals, precipitation of secondary minerals, mixing of waters, leaching of fertilizers and manure, pollution and biological processes (Appelo and

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Postma, 1993). Poor quality of water adversely affects plant growth and human health (US Salinity Laboratory Staff 1954; Todd 1980).Groundwater quality data gives important clues to the geologic history of rocks and are indicators of groundwater recharge, movement and storage (Walton 1970).Knowledge of hydrochemistry is essential to determine the origin of chemical composition of groundwater (Zaparozec 1972). Investigations associated with understanding of the hydrochemical characteristics of the groundwater, geochemical processes involved and its evolution under natural water circulation processes not only helps in effective utilization and protection of this valuable resource but also aid in envisaging the alterations in groundwater environment (Lawrence et al. 2000; Edmunds et al. 2006). Thus, determination of groundwater composition and its interpretation is very important for the evaluation of its suitability fordomestic, irrigation and industrial uses (Hwang et al, 2017). Shillong city has been exclusively relying on surface water sources viz., rivers and springs, but during recent years it has started using groundwater to meet the requirements of growing population. Hence the objective of the present study is to investigate the hydrogeochemistry of aquifers and to evaluate the suitability of groundwaterfor drinking and domestic purposeinShillong City.

Study area

Shillong, the present study area (Figure1), is the capital of Meghalaya and an agglomeration of municipal wards, townships and rural fringes. It is bounded between coordinates25°30'29"N - 25°42'10"N and 91°46'50"E -92°00'32"E and covers an area of about 208 sq.km. as per the Shillong Master Plan 1991-2011.

Geology and hydrogeology

The study area represents a dissected undulating plateau with an altitude varying between 1400 - 1900m abovem.s.l. Broadly four major geomorphic units can be identified in the study area viz., the structural hills, narrow river valleys, topographic low with sediments fill and large static water bodies. Structural hills composed of Shillong Quartzites and phyllites form the dominant geomorphic unit covering more than 90% of the area. The main urban growth centre of Shillong is situated on a broad topographic low with several flat topped low relief hillocks and gently undulating valleys. Umkhrahvalley which skirts the northern edge of the town, has been filled by sediments both colluviums and alluvium and is situated at a much lesser height than the Shillong plateau. The Umiam lake situated towards northern extremity of the city is the major storehouse of fresh water and all the main drainage of the study area feed into this reservoir.

Geologically the study area forms part of the Shillong Basinwith exposure of the Shillong Group of rocks comprising quartzites and subordinate phyllites along with meta-basic intrusives, locally known as Khasi Greenstone. Proterozoic igneous activity is represented in the southwesternfringe of the area

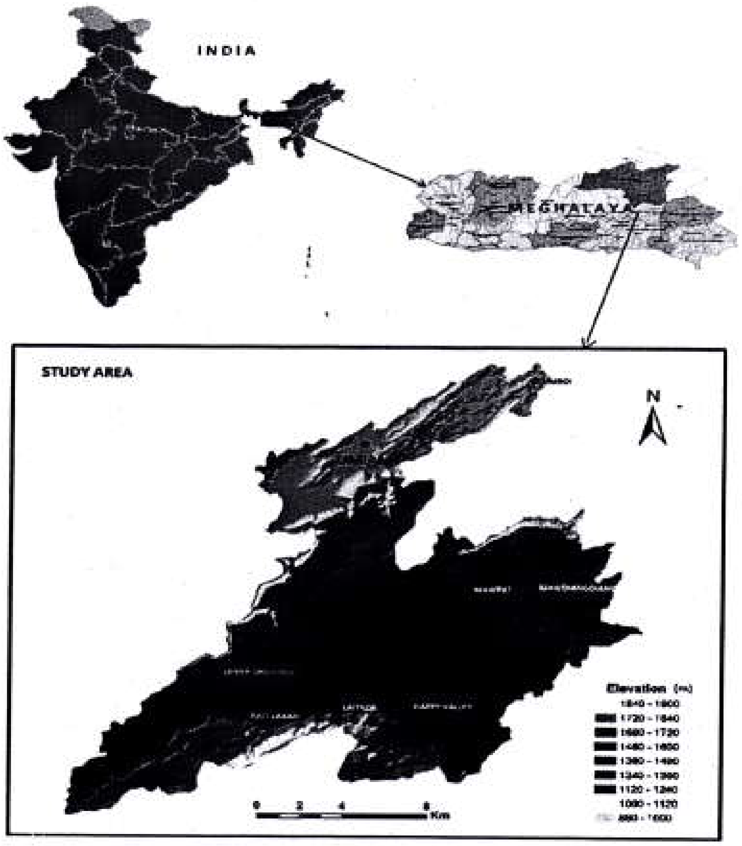


Figure 1: Location Map of the Study area

in the form of a few granite plutons (Mylliem Granite).A prominent shear zone (Tyrsad-Barapani shear zone) trending NE-SW is locatedat Umiam along G.S Road, in the northwestern corner of the area.The Shillong Group of rocks show higher amount of weathering in the topographic depression than in other areas. Themetabasic rocks are more prone to weathering due to their low interstitial porosity but high fracture porosity. The NE-SW direction of lineaments coincides with the strike direction of the rocks and has well developed joint sets.They hold prospect for development and controlling groundwater flow in the study area. Groundwater in the Shillong Group of rocks and crystalline intrusive, is found in fractures within the rocks .The main source of groundwater recharge in the study area is through precipitation brought about by southwest monsoon winds during the months of June to September.The high relief areas in the southern and south-eastern corner is occupied by Laitkor range and Shillong Peak with steep topographic slope and characteristic geological set-up.Theyoffer high run-off and little scope for rain water infiltration. Due to seepage of inland water numerous springs are also formed which is being used extensively for water supply in the area.

Methods

Hydrogeochemical Data

Groundwaterquality analysis for the present study was made based on the secondary data available with agencies like Central Ground Water Board (CGWB), Govt of India and Shillong Municipal Board (SMB),Government of Meghalaya(year 2014–2016).Analysis for hydrochemistry and hydrochemicalfacies was confined to Shillong city due to non-availability of data for the whole study area. Twenty-seven groundwatersamples were used for the analysis out of which twenty samples are of shallowwells (depth to well bottom from water table < 200 m) and sevensamples belong to springs water,which are used basically for domestic purposes in the study area.All groundwater samples wereanalysed for total dissolved solids (TDS), electrical conductivity (EC), hydrogen ion concentration (pH), iron (Fe^{2+}), turbidity, total hardness (TH), with major cation such as calcium (Ca^{2+}),magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+) and as well as anions such as carbonates (CO_3^{2-}),bicarbonates (HCO_3^-), sulphates (SO_4^{2-}), chlorides (Cl^-), nitrates (NO_3^-) and fluorides(F^-). For spring water,data of parameterssuch as chloride (Cl^-), total dissolved solids (TDS), hydrogen ion concentration (pH), iron (Fe^{2+}), and total hardness (TH). All values are given in milligram per litre, unless otherwise indicated.

A Piper TrilinearDiagram was used to infer hydrogeochemical facies and was plotted by using the software AqQA by Rockworks INC.USA. The Piper Trilinear Diagram (1944) is a combination of major cation and anion (expressed as a percentage of the total milliequivalents per litre) triangles that lie on a common base line. Adjacent sides of two triangles are the 60% apart. The percentage of major cations and anions in each sample is then plotted as a single point on the lower left and lower right triangles of the diagram, respectively. These points are projected to a single point on the plotting field, which lies between the two triangles. The Piper Trilinear Diagram (Figure 2) shows the percentage of the major cations and anions, i.e., the percentage of each constituent or group of constituents and is represented by where a point lies in the plotting field.

Calculation for Ion-exchange processes

Groundwater ion–exchange processes were calculated using the approach of Schoeller(1965, 1967). The ion exchange between the groundwater and its host environment during residence or travel can be understood by studying the chloro-alkaline indices:

$$\mathbf{CA\text{-}I = [(Cl^- - Na^+ + K^+)/Cl^-]}\ \text{and}$$
$$\mathbf{CA\text{-}II = [(Cl^- - Na^+ + K^+)/ (SO_4^{2-} + HCO_3^- + CO_3^{2-} + NO_3^-)]}.$$

Here, Na^+ and K^+ ions in water are exchanged with Mg^{2+} and Ca^{2+} ions.If the index value is positive, then it indicates baseexchange reaction whereas a negative value indicates chloro-alkaline disequilibrium. The reaction is known as cation- anion exchange reaction. During this process the host rocks are the primary sources of dissolved solids in the water.

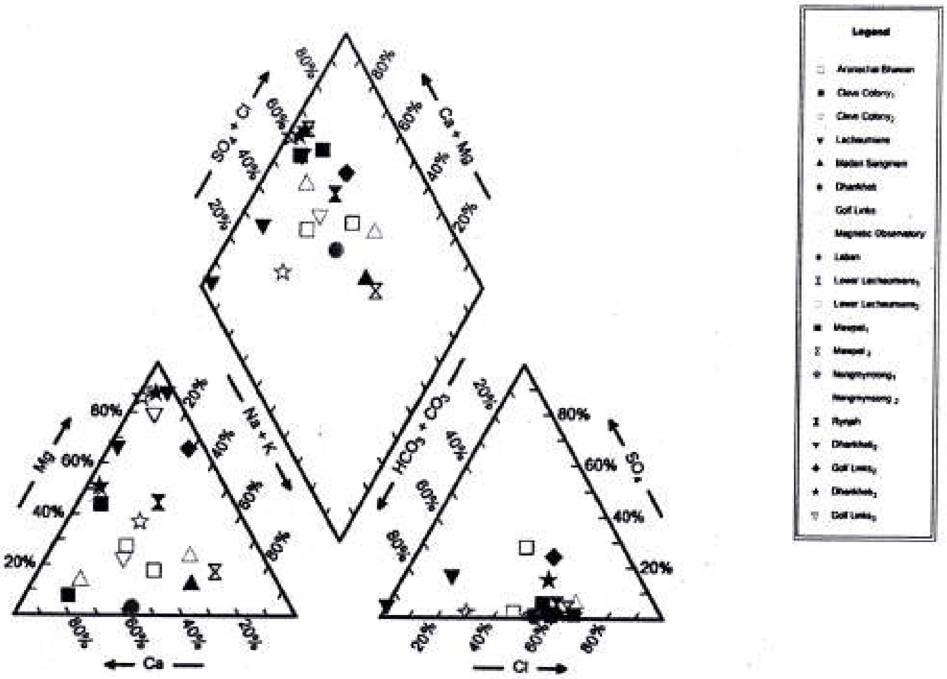


Figure 2: Piper Trilinear diagram of groundwater for the study area

Calculation of Water Quality Index (WQI)

For computing the water quality index (WQI) for the present study , seven water quality parameters have been considered, which include pH, TDS, TH, Fe^{2+}, SO_4^{2-}, Cl^- and NO^{3-}. The weighted arithmetic index method (Brown et al., 1972) has been used for calculation of WQI for the groundwater samples (Table 1). The quality rating or sub index (q_n) was calculated using the expression.

$$q_n = [(V_n - V_{io}) / (S_n - V_{io})] \times 100$$

Where,

q_n = Quality rating for the n^{th} water quality parameter

V_n = Estimated value of n^{th} parameter at a given sampling station.

S_n = Standard permissible value of n^{th} parameter.

V_{io} = Ideal value of n^{th} parameter in pure water. (*i.e., 0 for all other except the parameter pH= 7*)

Unit weight (W_n) was calculated by a value inversely proportional to the recommended standard value S_n of the corresponding parameter.

$W_n = K / Sn$

Where,

W_n = unit weight for the n^{th} parameter

S_n= Standard value of n^{th}parameter.

K= Constant of proportionality.

Calculation of the overall Water Quality Index was calculated by aggregating the quality rating with the unit weight linearly (Horton, 1965).

$$WQI = \Sigma q_n W_n / \Sigma W_n$$

Table1: Water Quality Index (WQI) and status of water quality (Brown et al, 1972)

Water Quality Index	Water Quality status
>25	Excellent Water Quality
26-50	Good Water Quality
51-75	Poor Water Quality
76-100	Very Poor Water Quality
>100	Unsuitable for drinking

Table2: Standards of selected water parameters and unit weights

Parameters	Standards (Sn)	Ideal value	Unit Weight(Wn)
TDS	500	0	0.0006
pH	6.5-8.5	7	0.0336
TH	300	0	0.001
NO_3^-	45	0	0.0064
Cl^-	250	0	0.0011
Fe^{2+}	0.3	0	0.9533
SO_4^{2-}	200	0	0.0014
ΣW_n= 0.9974			

Results and Discussion

The analytical results for all the geochemical data of groundwater and spring samples in the study area are summarised in Table 3 and statistical summary are tabulated in Table 4.

Table 3: Chemical composition of the various constituents in ground water samples of Shillong City

Sample ID	Source	Ca^{2+}	Mg^{2+}	Na+	K+	HCO_3^-	SO_4^{2-}	Cl^-	TDS	EC	pH	Fe^{2+}	F^-	Turbidity	NO_3^-	Hardness	CO_3^{2-}	CA-I	CA-II
Arunachal Bhawan	DTW	11.2	2.9	12.4	0.3	28	17.91	17.9	44.3	91.6	8.3	0.08	BDL	0.2	2	40	BDL	0.32	0.12
Cleve Colony_1	DTW	48	2.9	10.4	1.1	52	1.93	65.4	201	412	8	BDL	BDL	BDL	13	132	BDL	0.85	0.83
Cleve Colony_2	DTW	11.2	6.8	8.9	0.2	64	1.62	15.9	33.9	71.9	8.2	BDL	0.13	0.1	2.1	56	BDL	0.45	0.1
Lachaumiere	DTW	17.6	23.3	1.25	1.1	28	0.99	0.1	110	242.1	7.4	0.16	0.09	BDL	4.6	140	BDL	-0.50	-0.001
MadanSangmein	DTW	8	1.9	15.9	1.5	36	1.02	20.5	24.1	50.5	6.7	BDL	0.44	BDL	0.3	28	BDL	0.29	0.16
Dhankheti	DTW	30.4	1	20.8	7.1	56	0.99	44.4	117	256.2	9.5	5.1	0.38	BDL	2.7	80	8	0.69	0.45
Golf Links	DTW	16	1.9	4.1	0.5	28	0.99	20.5	53	116.6	8.1	0.01	0.25	BDL	1.5	48	BDL	0.82	0.55
Magnetic Obs. Campus	DTW	14.4	3.9	8.5	1.1	40	0.99	23.9	60.3	131.8	7.09	0.33	0.26	BDL	0.6	52	BDL	0.69	0.39
Laban	DTW	11.7	92	9.16	2.87	164	56	141	485	945	7.5	2.87	0.5	0.1	9.5	81.2	BDL	0.95	0.58
Lower lachaumiere_1	DTW	19.2	12.8	2.5	1.1	48	3.5	44	184.3	346.9	6.9	1.39	0.05	BDL	0.5	60	BDL	0.96	0.81
Lower lachaumiere_2	DTW	27.2	9.7	16.66	1.57	92	3	45.9	173	327.5	7.7	BDL	0.02	0.15	1.3	108	BDL	0.67	0.31
Mawpat_1	DTW	28.8	16	5.08	1.85	40	4.4	32	215	405.5	8.3	0.19	0.14	BDL	1.6	80	32	0.89	0.36
Mawpat_2	DTW	11.2	5.8	35.03	8.54	64	1.9	55.9	243.2	455.8	7.95	BDL	0.04	0.5	0.7	52	BDL	0.52	0.44
Nongmynsong_1	DTW	20.8	88	2.5	1.2	164	10.3	141	327.7	617.7	8.31	0.16	0.1	BDL	1.9	72	32	0.99	0.67
Nongmynsong_2	DTW	16	8.7	29.6	10.2	56	9.1	75.8	392	745.9	8.1	BDL	0.07	0.4	1.1	76	BDL	0.74	0.85
Rynjah	DTW	12.8	12.8	13.2	4.2	48	5.7	46	251	472.8	7.7	0.05	0.2	BDL	1.2	96	BDL	0.80	0.67
Dhankheti_2	DTW	1.9	40	7.5	1.05	64	12.8	9.5	71.95	143.8	8.38	1.05	0.19	0.2	0.19	12.57	56	0.32	0.02
Golf Links_2	DTW	2.9	20	15.82	1.02	18	12.8	19.3	26.81	53.27	8.33	0.41	0.37	0.6	0.37	8.08	36	0.23	0.06
Dhankheti_3	DTW	20.8	14.4	1.23	2.03	32	1.2	32	171.3	319.8	8.3	4.72	0.33	0.2	0.2	80	24	1.02	0.57
Golf Links_3	DTW	4.8	20.8	3.93	1.1	56	1.3	43.9	37.5	69.68	7.2	0.18	0.15	0.1	0.3	32	BDL	0.93	0.71
Risa Colony	Spring	NA	NA	NA	NA	NA	NA	18.1	30	NA	7.6	0.08	NA	NA	NA	6.6	NA	-	-
MadanLaban_S	Spring	NA	NA	NA	NA	NA	NA	18.1	112	NA	6.9	0.04	NA	NA	NA	6.6	NA	-	-
Madan Laban_1	Spring	NA	NA	NA	NA	NA	NA	18.1	36	NA	7.1	0.04	NA	NA	NA	6.6	NA	-	-
Madan Laban-2	Spring	NA	NA	NA	NA	NA	NA	18.1	48	NA	7.8	0.04	NA	NA	NA	6.6	NA	-	-
Malki_1	Spring	NA	NA	NA	NA	NA	NA	20.8	40	NA	7.3	0.08	NA	NA	NA	13.3	NA	-	-
Iewduh	Spring	NA	NA	NA	NA	NA	NA	18.1	36	NA	7.1	0.08	NA	NA	NA	8.8	NA	-	-
Malki_2	Spring	NA	NA	NA	NA	NA	NA	18.1	52	NA	7.1	0.08	NA	NA	NA	6.6	NA	-	-

*All values are given in mg/L except EC (μmho/cm), pH, Turbidity (NTU) and Hardness (mg $CaCO_3$/L). NA: Not Available, BDL: Below Detectable Limit

Source: Central Ground Water Board

Table 4: Statistical summary along with limits of drinking water quality.

Category Of Parameters	Characteristics		Maximum	Minimum	Mean	SD	WHO(2011)	IS(2012)
General	Dissolved Solids	TDS	485	24.1	132.46	122.54	NA	500-2000
	Conductivity	EC	945	50.5	313.82	246.70	NA	NA
	pH	pH	9.5	6.7	7.74	0.64	NA	6.5-8.5
	Iron	Fe^{2+}	5.1	BDL	0.63	1.37	NA	0.3
	Turbidity		0.6	BDL	0.13	0.18	NA	1-5
	Hardness		140	6.6	51.44	40.08	100	200-600
Major Cations	Calcium	Ca^{2+}	48	1.9	16.75	10.83	75	75-200
	Magnesium	Mg^{2+}	92	1	19.28	25.99	30	30-300
	Sodium	Na+	35.03	1.23	11.22	9.17	200	NA
	Potassium	K+	10.2	0.2	2.48	2.83	NA	NA
Major Anions	Bicarbonate	HCO_3^-	164	18	58.90	39.79	NA	300
	Sulfate	SO_4^{2-}	56	0.99	7.42	12.49	200	200-400
	Chloride	Cl^-	141	BDL	37.93	34.54	200	250-1000
	Nitrate	NO_3^-	13	0.19	2.28	3.29	50	45
	Fluoride	F^-	0.5	BDL	0.19	0.15	1.5	1.0-1.5
	Carbonate	CO_3^{2-}	56	BDL	9.40	16.78	NA	NA

NA: not available

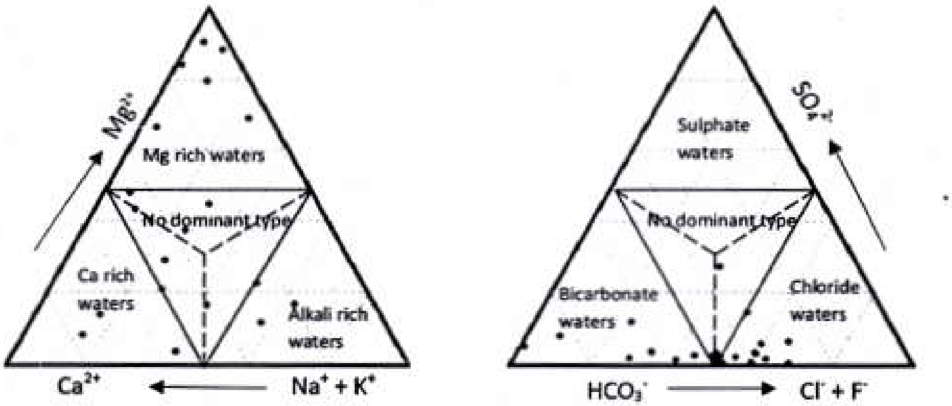
Hydrgeochemistry

The values of pH in the water samples collected from the study area ranges from 6.7 to 9.5, indicating a slightly acidic to alkaline water. All the samples showed a pH value within the safe limit as prescribed by IS-10500 (2012) except for one sample in Dhankheti, which showed a pH value of 9.5 which is beyond the permissible limit. Geochemically, pH is a significant control on the dissolution of certain naturally occurring metals or by the aquifer material (Carol et al., 2006). For instance, in oxidizing conditions, pH may be low because of dissolution of ferrous-containing minerals, whereas pH may rise because of hydrolysis of silicates resulting in a geochemical environment that is both alkaline and reducing (Garrels and Christ, 1965). In the present study, alkalinity increases at pH value greater than 6.

Specific conductance is a measure of the ability of a substance to conduct an electrical current and is reported in units of microsiemens per centimeter at 25 degrees Celsius (μS/cm). A significant variation of EC values was observed which ranged from 50.5 to 945μS cm^{-1} with a mean value of 313.82 μS cm^{-1} and a standard deviation of 246.70 μS cm^{-1}. The large variation in EC is mainly attributed to geochemical process like ion exchange, reverse exchange, evaporation, silicate weathering, rock water interaction, sulphate reduction and oxidation processes (Ramesh 2008).TDS varies in the range of 24.1 to 485 mgl^{-1} with a mean value of 135.55 mgl^{-1}. In the study area, the TDS concentration of all the groundwater samples was found within permissible limit (IS 2012). Higher concentration of TDS is observed in groundwater of Nongmyngsong and Laban, which is due to low groundwater table and the remaining with higher ground water table have lower concentration of TDS. As per TDS classification (Fetter 1990) all the groundwater samples are fresh water type (TDS < 1,000 mgl^{-1}). Water hardness is caused primarily by calcium and magnesium ions in solution. Total hardness as $CaCO_3$ in the study area ranges from 6.6 – 140 mg l^{-1} with a mean of 53.17 mgl^{-1}. According to Durfor and Becker (1964), hardness in groundwater is commonly classified as soft (0 to 60mg l^{-1}); moderately hard (61 to 120mg l^{-1}) and hard (121 to 180 mg l^{-1}).Of the total analysed samples, 63% of the groundwater samples fall under soft water, 30% were moderately hard water and 7% were hard water. Turbidity is a measure of the cloudiness of water (U.S. Environmental Protection Agency, 2005b). It occurs naturally in ground water, depending upon the aquifer medium. Turbidity values measured during this study ranged from BDL to 0.6 nephelometric turbidity units (NTU) with the mean value of 0.13 NTU. All the groundwater samples showed turbidity values within the safe limit as suggested by the IS (2012).Fe^{2+} concentration ranges from BDL to 5.1 mg l^{-1} and mean of 0.63 mg l^{-1}. 19% of the groundwater samples are beyond the safe limit as prescribed by IS (2012). The maximum concentration of dissolved iron was found in the wells of Dhankheti (5.1 and 4.72 mgl^{-1}) and Laban (2.87 mgl^{-1}).

Major ions

Major inorganic ions are calcium, magnesium, sodium, potassium, bicarbonate, chloride, and sulfate, which typically occur in natural water in concentrations of 1 mg/L or greater. These constituents exist in pairs of cations and anions, which are indicative of the mineralogy of the hydrogeologic setting through which the water has flowed (Carol et al., 2006). The hydrochemicalfacies is known to be affected by the rocks of the aquifer and the flow of groundwater and therefore groundwater can be classified based on the Piper diagram, using the distribution of cations and anions (Hwang et al., 2017). Figure 3 shows the dominant cations and anions in groundwater of the study area. Analytical result for cation chemistry (Ca^{2+} , Mg^{2+} ,Na^{+} ,K^{+}) shows that magnesium dominates the cationic components of the groundwater with 35% of the samples having magnesium-rich water followed by calcium with 15%; alkali rich water comprise 10% and remaining 40% plotted near the central zone having no dominant cation(Figure 3A). Among the alkaline earths, the concentration of Ca and Mg ions ranged from 1.9 to 48 and 1.0 to 92 mgl^{-1}, with a mean of 16.75 and 19.28 mg l^{-1}, respectively. Among alkalies, the concentration of Na and K ions ranged from 1.23 to 35.03 and 0.2 to 10.2 mg l^{-1}, with a mean of 11.22 and 2.48 mg l^{-1} respectively. None of the samples showed cation concentrations above the permissible limit of 200 mgl^{-1} and 300 mgl^{-1} (IS 2012).The concentration of major cations Mg,Ca,Na and K average 38.77%, 33.68%, 22.56% and 4.99 %.The order of abundance of major cations in the groundwater samples of the study is Mg >Ca> Na > K.



Figure

3A.Cation diagram relating Ca^{2+}, Mg^{2+} and Na^{+} ; B.Anion diagram relating HCO_3^-, SO_4^{2-} and Cl^-

For the anion chemistry (HCO_3^-, Cl^-, SO_4^{2-}, F^-, CO_3^{2-},NO_3^-), figure 3B shows that most of the ground water arebicarbonate (HCO_3). 40% of the samples fallunder this domain. 35% of the samples fall within the chloride domain and the rest of the samples falling within the central zone having no dominant anion. The concentration of HCO_3 , Cl, SO_4, NO_3, F and CO_3 ranges between 18 to164, 0.1 to 141, 0.99 to 56, 0.19 to 13, 0.5 – 0.01 and 0 to 56 mgl^{-1}, with a mean of 37.93, 7.42, 2.28,0.19 and 9.4 mgl^{-1}; all within the permissible limit . On an average the concentrations of major cations(in mgl^{-1})is 50.72%, 32.66%,8.10%,6.39%,1.96% and 0.16% . The order of abundance for major ions as anions in the groundwater is in the order of HCO_3>Cl> CO_3 > SO_4>NO_3>F.

Ion-exchange processes

Control on the dissolution of undesirable constituents in water is impossible during subsurface runoff, but it is essential to know the various changes undergone by waters during their trend (Johnson 1979).Schoeller indices values of the groundwater samples of the study area are given in Table-1 as C-1 and CA-2. It shows that cation-anion exchange (chloro-alkaline disequilibrium) exists only for the well of Lachumiere (negative value).99% of the wells showpositive values, indicating a base-exchange reaction (chloro-alkaline equilibrium).Groundwater with a base-exchange reaction in which the alkaline earths have been exchanged for Na+ ions (HCO_3^->Ca^{2+}+Mg^{2+}) may be referred to as base-exchange - softened water, and those in which the Na^+ ions have been exchanged for the alkaline earths(Ca^{2+}+Mg^{2+}> HCO_3^-) may be referred to as base-exchange- hardened water (Handa 1979). For the present study, since 80% of the groundwater samples have dominant HCO_3^- concentrationin comparison to the alkaline earths, therefore it can be concluded that base exchange-softened water is more abundant in the study area.

Hydrochemicalfacies

Piper Trilinear Diagram can define the patterns of spatial change in the water chemistry among geological units, along a line of section or along a path line (Raji and Alagbe, 1997; Domenico and Schwartz, 1998). The position of an analysis that is plotted on a Piper TrilinearDiagram can be used to make tentative conclusion about the origin of the water represented by the analysis (Hwang et al., 2017).The trilinear diagram conveniently shows similarities and differences among water samples, i.e., those with similar qualities will tend to plot together as groups (Todd and Mays, 2005).In the present study the results of geochemical data of ground water are plotted on Piper TrilinearDiagram (1944) to evaluate variations in hydrochemicalfacies.

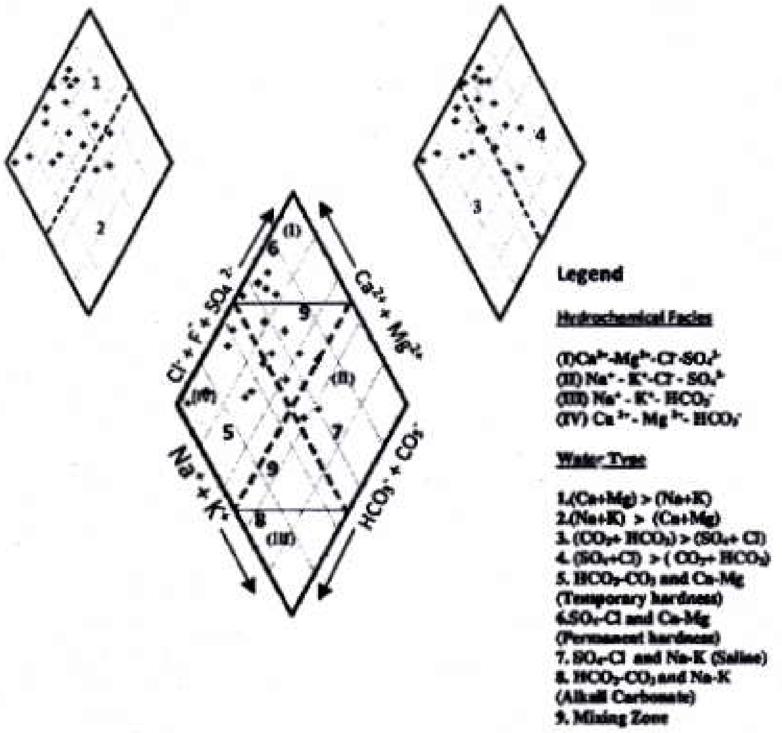


Figure4: HydrochemicalFacies shown on Piper's TrilinearDiagram and classification of water samples.

The Piper plot diagram (Figure 4) reveals that 50% of the samples plot within Ca^{2+}–Mg^{2+}–Cl^{-}-SO_4^{2-}field and 35% of the samples plot within Ca^{2+}–Mg^{2+}–HCO_3^{-} field, suggesting the presence of both permanent and temporary hardness in the groundwater of the study area (Table 5).The category Na^{+}-K^{+}-Cl^{-}-SO_4^{2-} typecontain 15% of the samples, indicating the relative low content of calcium and magnesium and relatively high content of sodium suggesting natural softening through base exchange (Piper, 1953).The figure also illustrate the dominance of alkaline earths over alkalies(Ca+Mg>Na+K), and strong acidic anions exceeding weak acidic anions ($Cl+SO_4>HCO_3$). An examination of Figure 4 demonstrates that35% of the samples fall in zone-5 belonging to secondary alkalinity indicating reverse/inverse ion exchange which is responsible for controlling the chemistry of the groundwater (Davis and Dewiest 1966).While those falling under zone 9(the mixing zone) comprise 30% of the groundwater samples wherenone of the cation-anion pairs exceeds 50%.Such types of groundwater cannot be identified as anion or cation dominant (Todd and Mays 2005).

Table 5: Classification of groundwater samples based on Piper TrilinearDiagram

Class	Groundwater type/ characteristics of corresponding subdivisions of diamond shaped fields	Samples in category: 20	
		No.of samples	%
I	Ca^{2+} - Mg^{2+} - Cl^{-} - SO_4^{2-}	10	50
II	Na^{+} - K^{+}-Cl^{-} - SO_4^{2-}	3	15
III	Na^{+} - K^{+}- HCO_3^{-}	-	-
IV	Ca^{2+} - Mg^{2+}- HCO_3^{-}	7	35
1	Alkaline earth(Ca-+Mg) exceed alkalies (Na+K)	17	85
2	Alkalies exceed alkaline earths	3	15
3	Weak acids(CO_3 + HCO_3) exceed strong acids (SO_4+Cl)	7	35
4	Strong acids exceed weak acids	13	65
5	HCO_3- CO_3 and Ca-Mg (temporary hardness); magnesium bicarbonate type (carbonate hardness exceeds 50%)	7	35
6	SO_4 – Cl and Ca-Mg (permanent hardness); calcium chloride type (non-carbonate alkali exceeds 50%)	4	20
7	SO- Cl and Na-K (saline); Sodium chloride type (non carbonate alkali exceeds 50%)	3	15
8	HCO_3- CO_3 and Na-K (alkali carbonate); sodium bicarbonate type (carbonate alkali exceeds 50%)	-	-
9	Mixing Zone (no one cation-anion exceeds 50%)	6	30

Around 20 % of the samples plot in zone 6, indicating permanent hardness category and exhibitcalcium chloride type wherein non-carbonate hardness exceeds 50 %, giving an indication of groundwater from active recharge zones with short residence time (Hounslow 1995). The remaining 15% of the samples plot in zone 7 having primary salinity (non-carbonate alkali) exceeding 50%, i.e, chemical properties are dominated by alkalies and strong acid and also indicating that the Na levels of these groundwater samples are largely dominated by alkali-silicate weathering or ion exchange reaction (Zhu et al., 2008; Wen et al., 2008).Both Na and K are equally common in the porphyritic granitic rocks that crop out over large part of the study area.

Water quality index (WQI)

WQI is commonly used for the detection and evaluation of water pollution and may be defined as a reflection of composite influence of different quality parameters on the overall quality of water (Horton, 1965).WQI is a valuable and uniquerating to depict the overall water quality status in a single term, which further helps in the selection of appropriate treatment technique to meet the concerned issues (Tyagi et al., 2013). Table 6 gives the results of WQIvalues.The data reveals that groundwater in the study area is excellent to unsuitable for drinking purpose. Of the total groundwater samples, 45% of the wells show excellent water quality , i.e, wells of Cleve Colony-1 and 2,Dhankheti-2,Golf Links-1, Laban, Lowerlachaumiere-2, Magnetic Observatory Campus and Mawpat-1.The well of Arunachal Bhawanshows good water quality,while groundwater samples from wells located at Lowerlachaumiere-1 and MadanSangmeinare categorized under poor water quality.The remaining 35% of the wells of Dhankheti-3, Golf Links-2and 3, Lachaumiere, Mawpat-2 and Nongmynsong-1and 2 are unsuitable for drinking purpose and require proper water treatment before use.

Table 6: WQI for the study area

Sl.No	Site	WQI	Sl.No	Site	WQI
1	Arunachal Bhawan	28.59	11	Laban	2.06
2	Cleve Colony-1	2.91	12	Lower lachaumiere-1	63.78
3	Cleve Colony-2	2.92	13	Lower lachaumiere-2	2.36
4	Dhankheti-1	52.42	14	MadanSangmein	54.23
5	Dhankheti-2	-0.56	15	Magnetic Observatory Campus	2.79
6	Dhankheti-3	1630.78	16	Mawpat-1	17.87
7	Golf Links-1	5.85	17	Mawpat-2	337.71
8	Golf Links-2	105.54	18	Nongmynsong-1	133.72
9	Golf Links-3	915.97	19	Nongmynsong-2	1507.01
10	Lachaumiere	442.84	20	Rynjah	57.93

Conclusion

Hydrogeochemical investigation of Shillong City shows thatmajority of chemical constituents are well within the permissible limits, except for concentration of dissolved iron. $HCO_3^-$and Mg^{2+} are the dominant anion and cationof the study area. The Piper TrilinearDiagram shows that there is a mixture of three types of water with variable concentrations of majorions, namely Ca^{2+}–Mg^{2+}–Cl^-–SO_4^{2-}, Ca^{2+}–Mg^{2+}–HCO_3^- and Na^+-K^+- Cl^--SO_4^{2-}. Groundwaterof the study area has secondary alkalinity and primary salinity.Schoeller indices values are positive except for one well which shows base-exchange reaction (chloro-alkaline equilibrium). 80% of the groundwater samples have dominant HCO_3^- concentration incomparision to the alkaline earths, indicating base exchange-softened water to prevail in the study area. TheWater Quality Index rating reveals that groundwater of the wells varies fromexcellent tounsuitable for drinking purposes. Overall the groundwater quality was suitable for drinking and domestic purpose except for few wells due to high iron content.

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ISSN 0000-023X

COVER DESIGN - SAMIRAN BORGOHAIN & T. CHALLAM