SSRG International Journal of Humanities and Social Science
ISSN: 2394-2703/ https://doi.org/10.14445/23942703/IJHSS-V10I1P101
Volume 10 Issue 1, 1-7, Jan-Feb 2023

Original Article

Assessment of Availability of Water at Various Domestic Water Sources in Aizawl City, Mizoram (India)

C. Ramhnehzauva

Department of Geography, Govt. Lawngtlai College, Mizoram

Received: 01 November 2022 Revised: 03 January 2023 Accepted: 14 January 2023 Published: 30 January 2023

***Abstract** - The prime water source is terrestrial precipitation, mainly in the form of rain. Its availability in the form of surface run-off and groundwater also depends upon the area's rainfall pattern, geological structure, and landforms. Like most hill towns, Aizawl faces acute water supply problems during the dry winter and early summer. The water-related needs of the people in the study area were met for generations by these natural water sources. However, water discharge in these sources has been depleting over the years; many have dried up while many more have become seasonal due to increasing population, neglect of the recharge areas and changes in land use. To solve the drinking water problem in the study area, the State government has been implementing several schemes, and millions of rupees have been pumped in, but the situation is far from satisfactory. The built environment of a city is a superimposition of its natural environment, particularly affecting water sources. As the city extends itself, the direct recharge from rainfall is less and lesser recharge leading to the depletion of available fresh groundwater potential at a fast rate on the one hand and the increasing infiltration on the other hand from diffuse pollution sources contaminate the groundwater. Therefore, in this paper attempt has been made to study the availability of water in different domestic water sources of Aizawl City.*

***Keywords** - Availability, Piped water supply, Tuikhur, Handpump, Rainwater.*

1. Introduction

Geographers have long regarded the study of water as an essential part of their discipline. The milestone contribution of geographers came in the form of an edited volume entitled '*Water, Earth and Man*' (Chorley, 1969), which defined the role of geographers in studying water resources through essays in the field of hydrology, geomorphology, and socio-economic geography. It included the views of geographers on the interrelation of hydrologic, geomorphic and human systems and noted some contributions geographers can make to actual water management (Chorley and Kates, 1969). In his book entitled 'Introduction to Geographical Hydrology', Chorley (1971) studied spatial aspects of the interactions between water occurrence and human activity.

Water is one of the most indispensable substances for man's daily life and survival. The depletion of surface and groundwater resources because of a growing population is the biggest threat to water maintenance. Because water is not managed effectively, pollution and water shortages threaten human life and the aquatic organisms that depend on freshwater for survival. Groundwater resources are also mismanaged and over-tapped because of uncontrolled extraction (Pimental, 2001). In the wake of the continuous increase in the world's population, the global water problem will become more serious (Raven *et al.*, 1995). The water problem is global but has regional variations in its nature. Over the past century, human water use has increased about twice as fast as population growth. Regional variations mainly arise due to differences in climatic and geomorphic conditions or the pattern and level of social and economic development (Cunningham and Saigo, 1995; W.R.I., 1995).

The total water availability in the world is about 525 million cubic kilometres, out of which over 96 per cent is saline. Of the total freshwater, over 68 per cent is locked up in ice and glaciers. Another 30 per cent of fresh water is below the ground. Thus, surface water sources (such as rivers) only constitute about 93,100 cubic kilometres, which is about $1/700^{th}$ of one per cent of total water, yet rivers are the source of most of the water people use (Gleick, 2000; Ward and Robinson, 1990). Annually, 300,000 cubic kilometres of precipitation occur over the oceans and 100,000 cubic kilometres over the land. The annual evapotranspiration from land is 60,000 cubic kilometres, 40,000 cubic kilometres is run-off from land to sea, and 340,000 cubic kilometres evaporate from the seas (W.R.I., 2000). With over six billion people living on the earth, nearly every country in the world experiences water shortages during certain times of the year. Between 1960 and 1997, the per capita availability of freshwater worldwide declined by about 60 per cent. Another 50 per cent decrease in per capita water supply is projected by the year 2025 (Pimental, 2001). Between 1950 and 2000, annual water availability per person decreased from 16,800 cubic metres to 6,800 cubic metres per year, calculated globally (Shiklomanov, 1997). Global concerns about water scarcity include not only surface water sources but groundwater sources as well. Some 1.5 billion people rely on groundwater sources, withdrawing approximately 600 cubic kilometres to 700 cubic kilometres per year, i.e., about 20 per cent of global water withdrawals (Shiklomanov, 2000).

The scarcity of renewable fresh water is a problem for millions of people worldwide. It is currently estimated that more than 430 million people live in water-stressed countries (UNDP, 2006). The present and future availability of fresh water in populated areas depend on the existing freshwater ecosystem and underground aquifers. Deterioration in the quality of surface water and groundwater becomes more likely and critical as nations become more industrialised and urbanised and as competing demands for water increase (F.A.O., 2003).

India has a relatively small proportion of the earth's water resources and landmass. With a population of 1.03 billion or 16 per cent of the world's total population, India has 329 million hectares or only about 2.5 per cent of the world's land resources and 4 per cent of the water resources. Precipitation plays an important role in India's water resources, the total precipitation, including snowfall, is about 4,000 billion cubic metres (B.C.M.). Of these, 1,869 BCM is available from surface water and renewable groundwater, but only 60 per cent or 1,122 BCM (690 BCM from surface water and 432 BCM from groundwater) can be used because of topographical and other constraints (NCIWRDP, 1999).

There are wide variations in the country's water availability, both temporal and spatial. Most of the rainfall is confined to the monsoon season, from June to September, and annual precipitation levels vary from 100 mm in western Rajasthan to over 9,000 mm in Meghalaya (Engleman and Roy, 1993). In its 2002-2003 Annual Report, the Ministry of Water Resources estimated that 5.5 per cent of the geographical area and 7.6 per cent population of the country were under absolute scarcity conditions. It said that water availability was less than 500 cubic metres per capita per year. The availability of fresh water per capita per year has come down in India from about 5,177 cubic metres per capita in 1951 to 1,820 cubic metres in 2001. It is expected to go down further to 1,140 cubic metres per capita per year by 2050 A.D. (*cf.* Sankarnarayan, 2005).

2. Study Area

Aizawl, the capital of Mizoram state, is situated on the hillcrests, steep slopes and small valleys. It is located on a north-south elongated ridge, which acts as the main hill from which many small ridges and valleys extend towards east and west directions. The topography is highly undulating and rugged. The unique physical attributes of this rugged land are marked by extreme fragility and frequent landslides, limited land space, steep slopes and lack of accessibility. The city reveals a rapid and uncontrolled growth pattern with multi-storey settlements that have mushroomed unplanned on highly risk-prone slopes. The altitude varies from 120 m to 1400 m above mean sea level. It falls between 23º 40' N to 23º 50' N latitudes and 92º 40' E to 92º 49' E longitudes. It covers an area of about 128.98 sq km, and as per Aizawl Municipal Corporation Report 2020, the population is 3,59,829 persons. There are a number of streams in and around Aizawl City, but none of them is dependable for providing adequate water. The only dependable source is river *Tlawng* located more than 1,000 m below the city.

3. Data Base and Methods

Information on the quantity of piped water supply per day and discharge volume of River *Tlawng* was collected from the Public Health Engineering Department (PHED), Government of Mizoram, Aizawl. The discharge of water from *Tuikhur* (i.e., water seepage accumulated in the artificially fabricated reservoir or spring water collected in the artificial tank) has been measured in three different months of 2019, such as February, July and December, to find out the seasonal fluctuations of the discharge. The water discharge in *Tuikhur* has been measured in the volumetric method, i.e., litres per minute (lpm). Discharge of water in eighty-six *Tuikhur*, distributed in fifty-two different village councils, has been measured. The discharge of water in the months of February and December was measured by collecting water using a small utensil to the vessel of known capacity, whereas in July (in most cases), water overflowed from the pits/tanks; in that case, the water flow from the pits/tanks was collected and measured. The static water level of hand pumps during the post-monsoon period is obtained from the Geology and Mining Wing, Directorate of Industries, Government of Mizoram, Aizawl. The climatic data such as rainfall, temperature and relative humidity for the last 20 years have been collected from the Directorate of Agriculture and Minor Irrigation, Mizoram, Aizawl. Rainwater harvesting potential is calculated using a suitable formula.

4. Result and Discussions

Several different water sources are used for domestic purposes in the study area. The piped water supply is highly inadequate and unreliable. Hence, a large number of people get water from small-scale water services. It has been observed that there are five different types of water sources where the people obtain water for domestic purposes, such as piped water supply, hand pumps, *tuikhur*, rainwater harvesting, and private water tankers. In order to study the availability of water in water sources, different water sources have been taken separately. The public water supply source, River Tlawng, flows more than 1000 m below the city's western border in a deep gorge. From May to October, it receives high intensities of rainfall. Table 1 shows the discharge volume of River *Tlawng* in different months. However, an assessment has not been made from April to July. The discharge volume between May and July is believed to be more than in the other months. It can be seen that the discharge volume is highly fluctuating in response to seasonal variations of rainfall. Therefore, it can be estimated that even during the driest month, the river has a discharge volume of at least 1982 litres per second, equivalent to about 180 million litres per day (M.L.D.). It indicates that the water availability in River *Tlawng* is more than enough to feed the entire population in the study area, even during the driest month. Certainly, nature has been bountiful in making Aizawl rich in water wealth, so much so that with proper development and management, the area can very well meet its domestic water needs from its own water sources. Though it has a fairly abundant surface water source close by, the community water supply system suffers from problems of inadequate infrastructure, poor maintenance, and inequitable distribution.

Table 1. Discharge Volume of River Tlawng

Assessment Period		**Discharge Volume**	
Month	Year	(litres per second)	(million litres per day)
September	2018	11910	1029.21
October	2018	4741	409.75
November	2018	3958	342.12
December	2018	3184	275.2
January	2018	2608	225.42
February	2018	2449	211.66
March	2018	2118	183.03
August	2018	15396	1330.48
Average		**5795**	**500.86**

4.1. Piped Water Supply

In respect of water supply, though significant progress had been made in the post-independence period, much more needs to be done. Until today, more than three lakh population shares Aizawl Greater Water Supply Scheme Phase I & II, which could only pump 22.99 MLD water. It signifies the magnitude of water scarcity in the city. Based on the Aizawl Municipal Corporation (A.M.C.) 2020 report, the population is 3,59,829 persons, and the Government of India Tenth Plan recommendation of standard norms of the per capita water supply (135 litres per capita per day), the water demand in the city worked out as around 48.57 million litres per day (M.L.D.). However, in the present situation, the PHED makes only about 22.99 MLD of water available to the City residents. Thus, it can be estimated that there is a large gap between the supply and the demand, which is as high as 25.58 MLD. A shortage of water supply in cities is often taken as a sign of government failure.

4.2. Tuikhur

Variation in the discharge of *tuikhur* (i.e., water seepage accumulated in the artificially fabricated reservoir or spring water collected in the artificial tank) during the dry and rainy seasons is an important criterion to determine the reliability of such water source. The highest and lowest discharge does not occur at the rains' beginning and immediate end but typically a couple of weeks later, depending on the soil characteristics. Since *tuikhur* are usually fed by shallow groundwater, water quantity may be an issue during certain times of the year. The sub-surface water storage actually maintains Tuikhur. The rainwater infiltrates and percolates down through the joints, cracks, and mainly in the weathered materials. This water is collected by digging a pit in the ground where the sub-surface water assembles but in very little quantity, particularly during the winter. No doubt, during the rainy season, there is sufficient flow and water is collected in pots, buckets and tins by lifting the water with a small utensil. *Tuikhur* is mostly located along hillsides, low-lying areas, or at the base of slopes. The discharge of eighty-six *tuikhur* (32.45 per cent) distributed in fifty-two different local councils have been studied (Table 2). The discharge is measured in litres per minute (lpm) in the months of February, July and December.

It has been observed that *tuikhur* shows measurable discharge fluctuation in response to seasonal precipitation fluctuations. The discharge ranges from 1 lpm in February to 30 lpm in July. The average discharge of *tuikhur* is calculated to be 5.06 lpm (S.D = 4.05). More precisely, the average discharge in February is estimated at 1.91 lpm (S.D = 0.56), 8.75 lpm (S.D = 4.74) in July and 4.51 lpm (S.D = 1.51) in December. The discharge not only varies in different months but also varies from one area to another. It is seen that the discharge also varies even within a short distance. In brief, *tuikhur,* located in the eastern part, have a higher discharge, followed by the western, southern, and northern part of the study area. Therefore, the discharge of *tuikhur* is higher during the monsoon. However, as soon as the rains stop, the discharge drastically declines in most of them. Due to lesser discharge in the lean period of winter and early summer, the water problem is aggravated in this period. It has been estimated that 265 *tuikhur* existing in the study area can supply around 0.73 MLD of water during the late winter and early summer (February to April), 3.34 MLD during monsoon (May to October) and around 1.72 MLD of water during winter (November to December).

Table 2. Discharge of Water in *Tuikhur* During Different Months (in litres per minute)

Name of Local Council	**Feb**	**Jul**	**Dec**
Sihphir	1.5	6	4
Durtlang	1.5	6	3.5
Durtlang LT	2	6	4
Thuampui	1.5	5	3
Zuangtui	2	6	4
Zemabawk	2.5	8	4.5
	1.5	6	3
Bawngkawn	1.5	6	3
	1	5	2
Chaltlang	2	7	4

	1	5	2.5
Ramhlun 'N'	1.5	8	4
	2	10	6
Ramhlun 'S'	3	25	8
	2.5	10	6
Chanmari 'W'	2	8	5
	1.5	6	4
Electric Veng	3	25	9
	2	10	6
Dinthar	2	7	4
Dawpui VT	2	18	7
	2	10	4
Vaivakawn	2	8	4
	1.5	6	3.5
Kanan	2	5	3
	1.5	7	4
Zotlang	1.5	6	3
Hunthar	2	6	3
Chawnpui	2	9	4.5
	1.5	6	4
Luangmual	1.5	5	3
Gov't Comp.	2	7	4
	1.5	6	3
Zonuam	1.5	8	5
	2	7	4
Chawlhhmun	2	8	4
	1.5	7	3
Tanhril	2.5	8	4
	2	8	5
Sakawrtuichhun	2.5	7	4
	1.5	6	3
Bethlehem Veng	2	18	5
	1.5	7	4
Ramthar	3	20	9
	3	18	7
Aizawl VL	2	7	4.5
	2	6	4
Dawrpui	1	7	3
Saron	3	30	8
Chhinga Veng	1.5	10	5
Armed Veng 'N'	2	17	8
	1.5	7	4.5
Tuithiang	3	12	6
Khatla' S'	3	12	7
	2	8	4
Bungkawn	2	8	4
Chite	3.5	12	7
Maubawk	2	7	4
	1.5	5	3
Lawipu	2	7	4
Tuikual 'N'	2	7	5
	1	6	4
Tuikual 'S'	2	8	4.5
	1	7	4
College Veng	2.5	8	5
	2	7	4
I.T.I	2	7	4
	1.5	6	3
Venghlui	2	12	6
	1.5	8	4
Republic Veng	3	20	9
	2	9	4
Upper Rep.	1	5	3
Salem Veng	2.5	8	5
	1	7	4
Venghnuai	2	8	4.5
	1	6	3.5
Tlangnuam	2	7	4
	1	6	3.5
Kulikawn	2	7	4.5
	1.5	6	3.5
Saikhamakawn	2.5	8	4
	1.5	5	4
Mission Veng	2	7	5
	2	10	6
Mission VT	2.5	7	4.5

4.3. Static Water Level

The water table is not a static level surface; rather, it is generally a sloping surface that shows many irregularities caused by differences in permeability of the water-bearing materials or by unequal additions of water to the groundwater reservoir at different places. In general, the shape of the water table conforms closely to the broad features of the topography. The water table does not remain in a stationary position but fluctuates up and down, much like the water in a surface reservoir. If the inflow to the groundwater reservoir exceeds the draft, the water table will rise; conversely, if the draft exceeds the inflow, the water table will decline. Thus, the rate and magnitude of fluctuation of the water table depend upon the rate and magnitude at which the groundwater reservoir is replenished or depleted. The factors controlling the rise of the water table in the study area are the amount of rainfall that passes through the soil and descends to the water table.

The water table fluctuates in response to changes in the seasonal conditions affecting recharge and discharge. Due to the groundwater body's recharge through southwest monsoon precipitation, the water table tends to rise during the rainy seasons. By mid-October, rainfall generally ceases in the area and recovery of the water table in response to monsoon precipitation is expected to be completed by November, causing the depth of the water table to be shallowest during these months. The post-monsoon period (November) static water level measurement taken from thirty-six selected hand pumps at different locations within the study area has been shown in Table 3. Due to the unavailability of other periods' water level data, it is impossible to study the magnitude of the seasonal fluctuation of the water table. However, it is expected that along with the onset of dry winter from December, the recession of the water table may occur, and the decline of the water table may be greatest from the month of January to February. The total recession may be attributed to the factors of evaporation, evapotranspiration, loss of water seepages and artificial discharge affected by withdrawals from dug wells and hand pumps as well.

Table 3. Static Water Level of Hand Pumps in Different Local Councils

Name of Local Council	Location of Hand Pumps	Static Water Level (*in metre*)
Durtlang Vengthar	Zuangtui Road	12.19
	Selesih Road	0.27
Durtlang	Near Presbyterian Church	13.01
Zemabawk	Near Jona Steel Works	10.51
	Near Forest Check Gate	4.69
Ramhlun' N'	Near S.A Church	1.4
	Near Lalthazuala House	5.79
Ramhlun' S'	Near Excel Enterprise	Ground Level
	Near M.H.I.P House	3.41
	Near Presbyterian Church	0.21
Electric Veng	Near Kai Stream	1.67
	Near B. Sailo House	13.35
Ramthar	Near Avon House	3.2
Chhinga Veng	Near Presbyterian Church	7.16
Bungkawn	Shivaji Tillah	1.09
Tuikual 'N'	Near V.L Nghaka House	4.96
Tuikual 'S'	Near S.A Hall	0.73
Dinthar	Near Transformer	0.97
Dawrpui Vengthar	Near C. Chawngkunga House	6.46
Vaivakawn	Near K.K furniture	0.73
Kanan	Near C.L Thlamuana house	4.45
Zotlang	Near K. Sangchhuma House	6.21
Chawnpui	Below Tawnluia House	3.65
	Near Khawnghinga House	2.24
Luangmual	Near Zotuikhur Spring	0.54
	Near Candy Bakery	3.65
Zonuam	Near Zonuam Spring	0.88
	High Court Road	6.09
Republic Veng	Near Presbyterian Church	5.6
	Near Holy Heart School	2.4
I.T.I veng	Road Side	4.99
Bethlehem Vengthlang	Near Jubilee Stone	8.16
Kulikawn	Near Spring	9.05
	C.P Road	0.21
Mission Vengthlang	Near Servicing Station	0.18
	Near SMTC Centre	6.73

The water level varies according to the local topography and geological setup. The static water level ranges from ground level in *Ramhlun' S'* to 13.35 m below ground level in *Electric Veng*. Therefore, the average post-monsoon water level is estimated at 4.36 m below ground level. The dispersion statistics show wide variations in water level (S.D = 3.82). It has been observed that the water level varies due to rugged topography, even within a short distance. Taking it altogether, the static water level is shallow on the western part and deeper on the northern part. Geology and Mining Wing has conducted geophysical resistivity surveys using Vertical Electrical Sounding (V.E.S) at six locations in Aizawl, viz. *Ramhlun South, Chanmari West, Electric Veng* and *Bawngkawn*. However, a geophysical survey has various limitations in hilly terrain and densely populated areas like Aizawl. Due to the limited extent of wide horizontal ground electrodes, separation is not possible. As a result, the V.E.S penetrated only up to 20 m to 34 m depths.

Further, water pipelines and electric posts disturb the electrical sub-surface characters. Therefore, they found that saturation zones are located at a depth of between 3 m and 18 m. Resistivities are within the range of 40 ohms to 100 ohms. In some localities, high resistance material, i.e., the unsaturated layer of 1 m to 4 m thick, is found to intercalate the saturated zones.

4.4. Water Tanker

Inadequate and unreliable piped water supply, absence of rain and depletion of water in *tuikhur* during winter and the beginning of summer have provided an opportunity for commercial water tankers service to operate in the study area. The water tankers bridge the gap between demand and supply and provide water to a large number of families. Tankers supply water to mostly middle and upper-class families. The supply is more developed during winter when there is a piped supply shortage and availability of water in other sources is considerably declined. The amount of water purchased depends on the socio-economic status of the households and the size of the water storage tank they possess. Due to the depletion of water in water sources, generally, a water tanker takes nearly three hours to fill up a tanker. Thus, 200 tankers plying in the study area are estimated to make at least three trips per day each during the dry season, roughly equivalent to delivering about 1.5 million litres per day.

4.5. Rainwater Harvesting Potential

Even though the city enjoys high rainfall, it suffers from water shortage. This is because the rainwater is not conserved and allowed to drain away. The rainwater harvesting system in the study area can support domestic water for only a few days or only during rainy days. To look at the potential of rainwater harvesting, it is essential to look at the climate, especially rainfall patterns. The climate is equable, with very little seasonal fluctuation. January, the coolest month, has a mean temperature of 17. 41 °C, and June, the warmest month, has an average temperature of 24.94 °C. As mentioned earlier, the mean annual rainfall is 2,242 mm. More than 75 per cent of the annual rainfall occurs during the five months (May to October). Here an attempt has been made to assess the quantity of rainwater falling over the city and individual houses.

4.5.1. Total Rainwater Falling Over the City

Aizawl City Area = 128.98 sq km or 128,980,000 sq m
Annual Average Rainfall = 2,242 mm or
2.24 m (height of rainfall)
Therefore, 128,980,000 x 2.42
= 288,915,200 cubic metres or 288,915,200,000 lts
= 791.54 million litres per day (M.L.D.)

Assuming only 10 per cent of rainfall is harvested, the quantity of rainwater that can be harvested is worked out to 79.15 MLD. This is a sizeable quantity compared to the current water supply, which is much greater than the city's requirement. Thus, on average, 286 billion litres of water falls in the study area per year, whereas the annual water requirement is approximately 12 billion litres, which is only 4.20 per cent of the total rainwater falling over the city per year. In other words, if the study area has to depend only on rainwater, it needs to find a way to save about 5 per cent of the total rainfall in a year.

4.5.2. How Much Water Can Be Harvested From Individual House

The formula for calculating the amount of rainwater that can be harvested is as follows:

Run-off = A x R x C

Where,
A= Area of the catchment,
R=Rainfall,
C=Runoff coefficient

Rainfall means the amount of average rainfall either for a month or a year. The catchment of a water harvesting system is the surface, which receives rainfall directly and contributes water to the system. Run-off is the term applied to the water that flows away from a catchment after falling on its surface in the form of rain. The run-off coefficient is the ratio of the volume of rainwater that runs off a surface to the volume of rainwater that falls on that surface (Gould and Petersen, 1999). This also includes losses from spillage in the gutter system. A carefully designed and constructed gutter system is essential for any catchment system to operate effectively. A properly fitted and maintained gutter down-pipe system is capable of diverting more than 90 per cent of all rainwater run-off from a good roof catchment made of corrugated metal sheet into the storage tank, but the long-term collection efficiency is usually between 80 and 90 per cent (Lee and Visscher, 1992). Table 4 gives the range of run-off coefficients for roof and ground catchments.

For example, if a house roof in Aizawl is corrugated metal sheets with an area of 20 sq m, one can harvest about 35,840 litres of water in a year.

Area = 20 sq m
Rainfall = 2,242 mm or 2.24 m
Runoff Coefficient = 0.8
Runoff = 20 x 2.24 x 0.8) = 35.84 cubic metres or 35840 litres

Table 4. Run-off Coefficient for Various Roof Surfaces

Types of Catchment	Co-efficient
Roof catchments	
Sheet metal	0.8 - 0.9
Cement tile	0.6 - 0.7
Clay tile (machine-made)	0.3 - 0.4
Clay tile (hand-made)	0.25 - 0.3
Ground catchments	
Concrete-lined	0.75
Cement soil mix	0.30 - 0.40
Buried plastic sheet	0.30 - 0.35
Compacted loess soil	0.10 - 0.20

Source: Pacey and Cullis, 1986; Zhu and Liu, 1998.

Therefore, for a family of five members, this amount of water can supply for 179 days at the rate of 40 lpcd.

Water storage capacity is required to balance out the difference between rainwater supply and household demand. If the rainwater supply exceeds demand in any given month, storage is needed to allow this water to be carried over and used in a future month. Two conditions must be met for a rainwater system to provide total year-round water. First, the total rainwater supply must exceed the total demand. Second, there must be sufficient storage capacity to allow enough surplus water collected in wetter periods to be carried over to meet the demand in drier periods.

5. Conclusion

Water supply assumes serious public concern and interest as the State government, despite its efforts to provide enough drinking water to the people through pipelines, could not achieve much success. The winter season is dry as most water sources are dried-up, or the yield is reduced considerably. Moreover, it is a period of scanty rainfall as well. The water scarcity for domestic consumption in the city has turned very acute. Most families are subjected to heavy rationing of water for domestic purposes. The people are apprehensive that the water scarcity will worsen further if the state administration's water supply programme does not improve considerably. As the piped water supply fails to satisfy the domestic water demand, virtual water scarcity is created in the city. Despite the area receiving a good amount of monsoon rains, it has become water scarce. In such a situation, the city has become a playground of the owners of the water tankers who happily eke out a lucrative business during the dry winter and early summer.

As the average annual rainfall is sufficient in Aizawl, there should be no water scarcity. However, since the rainfall is not uniformly and regularly spread throughout the year, considerable water availability variations occur in water sources that create water scarcity.

References

[1] Richard J. Chorley, *Water Earth and Man: A Synthesis of Hydrology, Geomorphology and Socio-Economic Geography*, Mathuen and Company Ltd., London, p. 612, 1969. *Crossref*, https://doi.org/10.4324/9781003170181

[2] Richard J. Chorley, *Introduction to Geographical Hydrology*, Mathuen and Company Ltd., London, 1971.

[3] R.J. Chorley, and R.W. Kates, *Introduction, In Water, Earth and Man: A Synthesis of Hydrology, Geomorphology and Socio-Economic Geography*, Mathuen and Company Ltd., London. pp. 1-7, 1969.

[4] William P. Cunningham, and Barbara Woodworth Saigo, *Environmental Science – A Global Concern*, Wm. C. Brown Publishers, London. p. 612, 1995.

[5] Engleman, R., and LeRoy, P., *Sustaining Water: Population and the Future of Renewable Water Supplies, Population and Environment Programme*, Population Action International, pp. 55-56, 1993.

[6] FAO-Food and Agriculture Organisation, Review of World Water Resources by Country, Food and Agriculture Organisation of the United Nations, Rome, 2003.

[7] Peter H. Gleick, *The World's Water, 2000-2001: The Biennial Report on Fresh Water Resources,* Island Press, pp. 817-823, 2000.

[8] J. Gould, and E. Nissen-Petersen, *Rainwater Catchment Systems for Domestic Supply: Design, Construction and Implementation*, IT Publishing, UK, London, 1999.

[9] Lee, M.D., and Visscher, J.T., *Water Harvesting: A Guide for Planners and Project Managers*, Technical Paper Series No. 30, IRC International Water and Sanitation Centre, The Netherlands, The Hague, 1992.

[10] NCIWRDP- National Commission for Integrated Water Resources Development Plan, Integrated Water Resources Development – A Plan for Action, Ministry of Water Resources, Government of India, New Delhi, 1999.

[11] Pacey, A., and Cullis, A., *Rainwater Harvesting: The Collection of Rainfall and Runoff in Rural Areas*, ITDG Publishing, UK, London, 1986.

[12] David Pimentel, *Our Fragile World: Challenges and Opportunities for Sustainable Development*, World Natural Resource Policy and Management, pp. 169-182, 2001.

[13] Wandra Arrington, "Water Recycling: Benefits and Risks," *SSRG International Journal of Agriculture & Environmental Science,* vol. 9, no. 4, pp. 21-25, 2022. *Crossref*, https://doi.org/10.14445/23942568/IJAES-V9I4P104

[14] P.H. Raven, L.R. Berg, and G.B. Johnson, *Environment,* Saunders College Publishing, New York, 1995.

[15] Sankarnarayan, K., "Urban Water Supply – Challenges Ahead," *Proceeding XII World Water Congress of the International Water Resources Association*, 2005.

[16] Shiklomanov, I.A., *Comprehensive Assessment of the Freshwater Resources of the World: Assessment of Water Resources and Water Availability in the World*, World Meteorological Organisation and Stockholm Environment Institute. Stockholm, Sweden, 1997.

[17] Shiklomanov, I.A., *World Water Resources and Water Use: Present Assessment and Outlook for 2005*, World Water Scenarios: Analysis, World Water Vision, 2000.

[18] M.Arumaiselvi, and R.R.Tharini, "Evaluation of Groundwater Quality and Its Suitability for Domestic and Irrigation Purpose in Cuddalore District," *SSRG International Journal of Civil Engineering,* vol. 6, no. 4, pp. 13-16, 2019. *Crossref,* https://doi.org/10.14445/23488352/IJCE-V6I4P104

[19] UNDP-United Nations Development Programme, Human Development Report 2006, Beyond Scarcity: Power, Poverty and the Global Water Crisis, United Nations Development Programme, New York, 2006.

[20] Ward, R.C., and Robinson, M., *Principles of Hydrology,* 3rd Edition, Maidenhead, McGraw Hill, New York, 1990.

[21] WRI-World Resources Institute, *World Resources 1994-95: People and the Environment*, Report Prepared by World Resource Institute in Collaboration with United Nations Environment Programme and United Nations Development Programme, Oxford University Press, Bombay, 1995.

[22] WRI-World Resources Institute, *World Resources 2000-2001: People and Ecosystems: The Fraying Web of life*, Washington DC, 2000.

[23] Qiang Zhu, and Li Yuanhong, "Rainwater Harvesting for Sustainable Development of Water Resources in China," *Proceeding of International Water Symposium*, Stockholm, Sweden, 1998.