Training Manual

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Identifying Water Problems in India: Guidelines for Simplified and Easy to Perform Hydrogeological Investigations

Women's Action towards Climate Resilience for Urban Poor in South Asia

Lead

Mahila Housing SEWA Trust, Ahmedabad

Dharmistha Chauhan, M.A. and M.Phil.

Bijal Brahmbhatt, B.Sc., Director of MHT

Cooperation Partner

Freie Universitaet Berlin

Theresa Frommen, M.Sc.

Dr. Maike Groeschke

Prof. Dr. Michael Schneider

Project Funding

Global Resilience Partnership

The Rockefeller Foundation

USAID

SIDA

Contact

Freie Universitaet Berlin · Institute of Geological Sciences · Hydrogeology Group
Malteserstraße 74-100
12249 Berlin – GERMANY
www.fu-berlin.de/hydrogeology

Author: Theresa Frommen, M.Sc.
Contributions by: Prof.Dr. Michael Schneider; Dr. Maike Groeschke; Kolja Bosch, M.Sc.; Carolin Winter, B.Sc.
Layout: Maximilian Noelscher, B.Sc.

Draft Version, Jaipur, November 2017

Content

1 Introduction

1.1 Global Resilience Partnership

This training manual was prepared within the project „Women's Action towards Climate Resilience for Urban Poor in South Asia" under the lead of Mahila Housing SEWA Trust (MHT), an autonomous organization promoted by the Self-Employed Women's Association (SEWA). The project took place in the frame of the Global Resilience Partnership (GRP) funded by The Rockefeller Foundation, USAID and Sida for a period of two years (2016-2017). The project aimed at empowering women from slums in seven South Asian cities (Ahmedabad, Bhopal, Jaipur, Ranchi, Bhubaneshwar, Dhaka and Kathmandu) to take action against the most pressing climate change related risks: heat waves, flooding, water scarcity and water and vector borne diseases. The interdisciplinary team included experts in urban planning, social sciences, urban health systems, water sciences, insurance and communication. Within this team, the Hydrogeology Group of Freie Universitaet Berlin (FUB) was responsible for hydrogeological investigations in two study areas in Jaipur, Rajasthan, to develop a community-based water management. The present manual is based on the experiences gained during the 1.5-year long field study in Jaipur (mid 2016 until end 2017).

1.2 How to Use the Manual

The manual is designed for the use by NGOs working with poor communities and wanting to develop or improve their WASH (water, sanitation, hygiene) programs by integrating hydrogeological knowledge into their actions. It is a training manual with three units to enable women and youth to understand and assess the water (and sanitation) situation in their communities under the guidance of a local organization.

In this first chapter the purpose and structure of the manual is explained (Section 1.2) and an exemplary time schedule for the implementation is given (Section 1.3).

The second chapter "Understanding" is the first unit of the training course. It includes information about the general water situation in India and an introduction to groundwater hydrogeology as well as suggestions and supporting materials on how to convey this knowledge in water workshops. Descriptions of interactive tools are given at the end of each section. They help to transfer the knowledge and, at the same time, keep the motivation and concentration of the participants at a high level. This is important as most of the participants are not used to concentrate for a long time. The supporting materials to conduct the interactive tools are given in the Annex. The tools can be used exactly as described but they can also serve as a source of inspiration to add other interactive tools. With this unit awareness building - the first level of participation - should be achieved. The workshops should be conducted for a broad group in order to create a wide spread awareness about groundwater. This will be important at a later stage, if measures will be implemented which include the necessity of behavior change of the local people/within the community.

The following Chapters 3 and 4 are designed for working with a small group of people. Chapter 3 "Observing" covers the second unit of the training manual and describes important water quantity and quality parameters and how to measure them. Supporting material for the field work are given in the Annex. With this unit active involvement - the next level of participation - is achieved. It is time-intensive and requires a certain level of understanding, therefore, this work should be done with the most dedicated and interested women. Chapter 4 "Data Management and Assessing" comprises the last unit of this manual and is closely connected to Chapter 3. It shows simple ways to plot the data obtained in the previous unit and how to make a first assessment of them.

In Chapter 5, the hydrogeological terms used in the manual are summarized and shortly explained. Furthermore, their respective translation into Hindi is given. This chapter serves as a handy reference for users unexperienced in the field of groundwater.

It is highly recommended to read the manual carefully before starting to work with it.

The present Training Manual is the first part of a two-part series. The second part will comprise the Guideline Manual "How to solve your local water problems: Guidelines to the implementation of simple solutions".

1.3 Exemplary Time Schedule

This schedule includes the workshop, the mapping and the water quality measurement part. The part for water quantity measurement is not yet included.

The purpose of this time schedule is to give a rough idea about how long the implementation of this program would take and a reasonable order of the steps.

- Month 1: reading and understanding the manual (1 week) – preparing the workshop (2-3 days) – conducting the workshop (2 days) – identifying local women assistants for further cooperation (~2 weeks, depending on how good someone already knows the women)
- Month 2: meeting local women assistants to explain the project in detail (1 day) – preparing mapping of the area of interest (1 week) – conducting of the mapping (1-2 weeks) – preparing map of the area with all local water points identified during mapping (1 week)
- Month 3: preparing of the water testing (2 weeks) – meeting the local women assistants to teach how to take a water sample (1 day) – meeting the local women assistants to decide on monitoring points and monitoring interval (1 day) – conducting the water sampling in the field (1 week, depending on the number of monitoring points)
- Month 4-6: conducting of the water sampling on a monthly basis (otherwise local women assistants may forget how to take the sample)
- From month 6/7 on: conducting of the water sampling every 2 months (or less, minimum twice a year)
- Month 7: preparing of the data management and interpretation (1 week) – meeting with local women assistants to explain water quality record sheets (1-2 days) – implementing of the data management and interpretation (1 week)
- From month 8 on: conducting of the data management and interpretation after every sampling campaign

<u>Hints and Tips:</u>

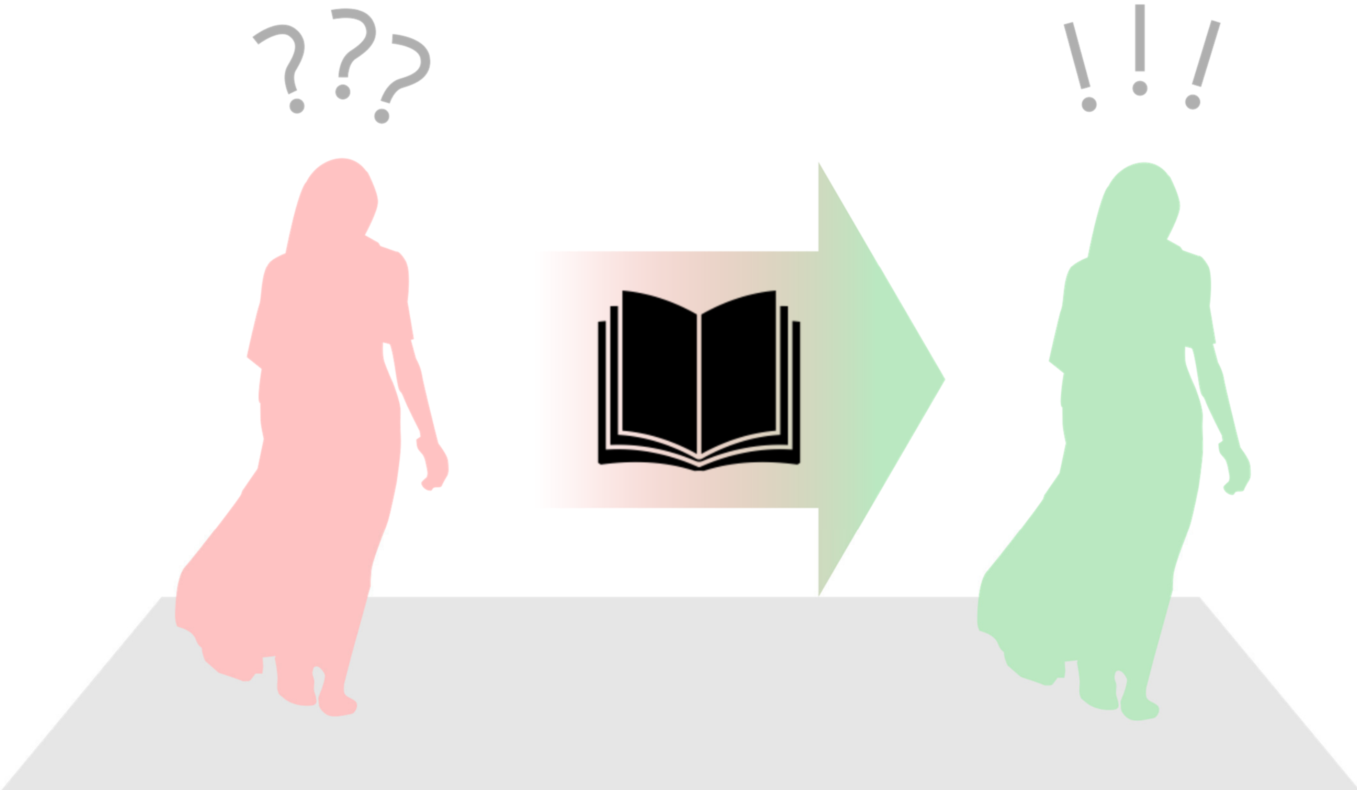
- Do the sampling on consecutive days and, if this is not possible, do it as close as possible. This is important to make the results from all monitoring points comparable.
- Normally, the women are able to conduct one water sampling a day but you should try to go for two samples a day. It will help to obtain all samples in a short time frame (see previous

point) and it will decrease the organizational effort.

- Start with the interpretation of the data when the water sampling is well understood by the women and they are confident with the procedure. This is probably after 4-5 sampling campaigns.
- All timings are only rough estimates based on the experience gained during the field work in Jaipur (2016-2017).

2 UNDERSTANDING – UNIT 1

The urban water cycle and how human actions can influence the local water situation.



This chapter serves as a tool to create a basic awareness and knowledge about groundwater among people who deal with it every day without understanding basic hydrogeological processes. The sessions are designed to be used with a large group (~30 participants per workshop).

2.1 Water in India

2.1.1 Short Overview

Water availability is an important factor for the Indian economy. Rainfall constitutes the main source of water for agriculture and livelihoods during the monsoon which effects most parts of India. Nevertheless, the rainfall patterns in the different regions show a high temporal and spatial heterogeneity varying between abundant rainfalls > 2000 mm/a to scanty rainfalls < 500 mm/a (Baumann, 2001). The erratic nature of monsoonal rainfall is a huge challenge for water management in most regions in India. Heavy rainfalls in mountainous and hilly regions are often associated with inundations and soil erosion while scanty rainfalls are a major danger for the water availability.

The spatial distribution of annual rainfall in India is shown in Figure 1, revealing regions of abundant rainfall in the east and in the western coastal zones of India. Scanty rainfalls mainly affect the northwest and the southern central part of India.

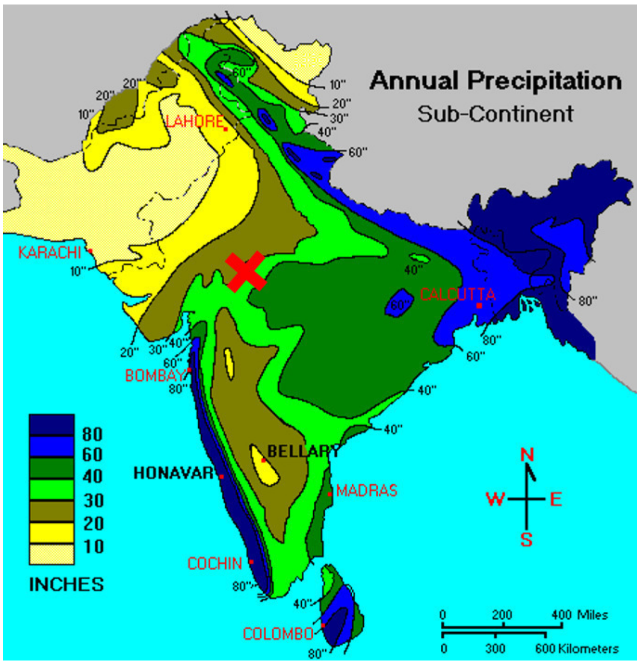


Figure 1: Mean annual precipitation in India (Baumann, 2001).

Rainfall and seasonal glacier melting in the Himalayan regions contribute a considerable volume of water to the north Indian river systems, including the Ganga, the Indus and the Brahmaputra catchments.

About half of the water demand in India is satisfied by surface waters. One third of the water demand is satisfied from groundwater, which constitutes a major water source for agriculture. The remaining 15 % of the water demand are faced by direct use of agricultural drainage water (FAO,2011).

More than 90 % of the water withdrawal in India is used for agricultural purposes. The remaining 10 % of the water demand originate from municipalities and industries (FAO,2011).

Interactive Tool: Questions

In order to involve the participants during the workshop and to get an understanding of their perception of water in India following questions can be asked:

1) Do you know where the water in India in general comes from? *(ppt, Page 2)*

2) What do you think, who are the biggest user of water in India? Industry, agriculture or households? *(ppt, Page 4)*

3) What do you think, what is the most important source of water in India? Surface water or groundwater? *(ppt, Page 5)*

Supporting material: PowerPoint presentation

Name: WaterWorkshop_Session1_OverviewIndia
Pages: 1-5

2.1.2 What are the Reasons for Water Problems in India?

India is facing increasing water problems both in quality and in quantity. Reasons for changes in water quantity and quality are:

- **Population growth** → per capita water availability will decrease

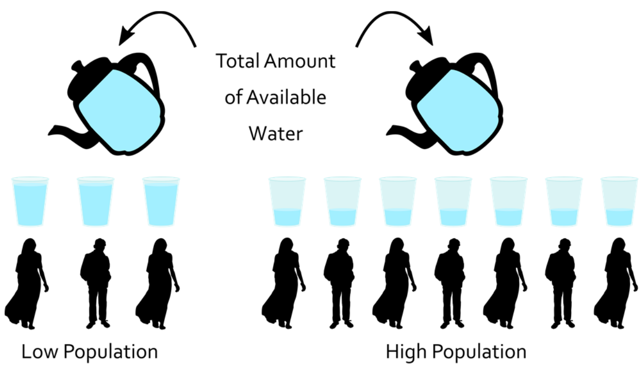


Figure 2: With population growth the available per capita amount of water is decreasing.

The available amount of water is shared among all people in one country. As every year more and more people are living in India, but the amount of water stays the same, every person has less water available for him-/herself (Fig. 2).

- **Urbanization** → population growth in cities is faster than infrastructure development

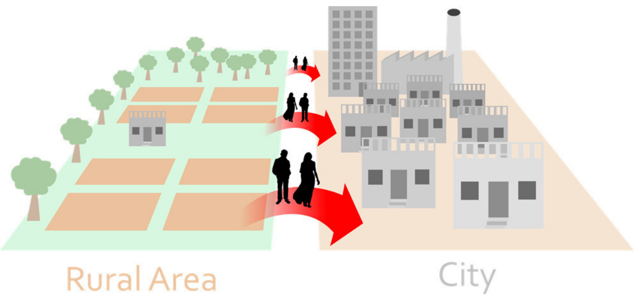


Figure 3: In India, many people from rural areas are moving to the cities.

The cities of India are growing very fast (Fig. 3), faster than the infrastructure for water supply and wastewater treatment can be constructed. Therefore, many people do not have a drinking water connection and untreated wastewater is discharged into the environment contaminating surface water, soil and groundwater.

- **Economic growth** → higher water demand, e.g. in industry sector and increased waste water production

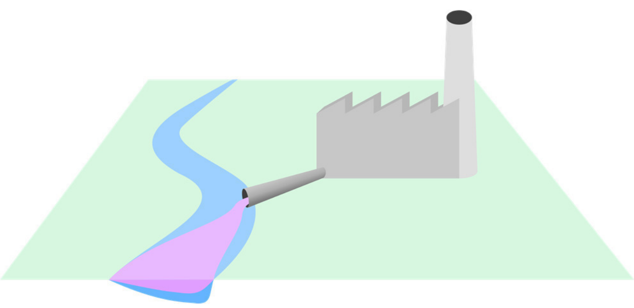


Figure 4: With an increasing industry sector the discharge of untreated waste water into the environment increases too.

With economic growth, India's industry is growing rapidly, but many industries require a lot of water which is then no longer available for domestic needs. Furthermore, industry often produces a lot of wastewater. If not properly treated, this wastewater harms the quality of other water sources, e.g. groundwater and surface water (Fig. 4).

- **Climate change** → glacier melting in Himalaya and change of monsoon patterns

Figure 5: Impacts of climate change: Flood in Mumbai (Associated Press, 2012) and drought in Telangana (Seelam, 2015).

With higher temperatures, the amount of river water coming from the glaciers of the Himalaya will first grow due to higher melting rates. But at a certain point, glaciers will be too small, so that every year there is less water in the rivers. Increasing temperature also leads to an increase in evaporation and, therefore, to a decrease in groundwater recharge. Furthermore, monsoon patterns change, which is especially problematic for farmers who rely on these patterns for cultivating their fields, supplying the food for India (Fig. 5).

Interactive tool: Questions

In order to involve the participants during the workshop and to see what they know about water and get an understanding of their perception of water following questions can be asked:

1) What do you think, what are the reasons for the water problems in India? (ppt, Page 6)

2) Why do you think it is important to know more about water and groundwater? (ppt, Page 10)

Supporting Material: PowerPoint presentation

Name: WaterWorkshop_Session1_OverviewIndia
Pages: 6-10

2.2 The Water Cycle

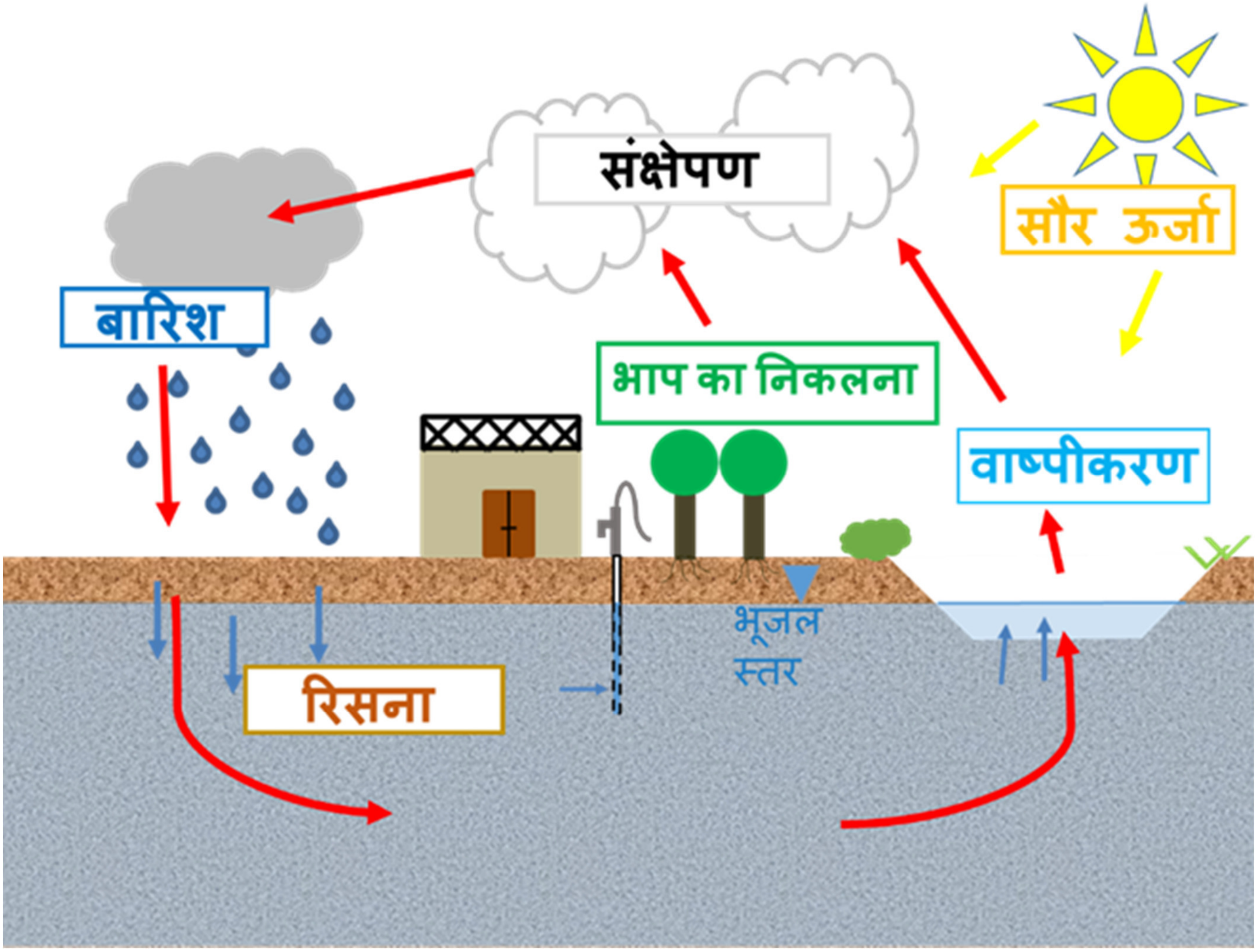


Figure 6: Simplified schematic of the water cycle.

A first step to understand the occurrence and possible uses of groundwater resources is to understand that the water on earth (atmospheric water, soil water, surface - and groundwater) is moving in cycles. As a result, changing one part of it will also influence the other parts. Figure 6 shows the water cycle including processes above and below the ground surface. In the following section, the most important terms will be briefly explained to you.

Solar energy (सौर ऊर्जा): Energy from the sun in the form of heat and light. It enhances transpiration and evaporation and is therefore one of the most important driving force for the water cycle.

Evaporation (वाष्पीकरण): The process when water on bare surfaces (no vegetation) is transferred into vapor which goes into the atmosphere. This process is driven by solar energy (heat).

Transpiration (भाप का निकलना): Loss of water from the soil caused by plants (uptake of water through the roots, transport of water through the plant and water vapor released from the leaves).

Condensation (संक्षेपण): Water in the atmosphere, in form of vapor, is changing back into liquid water in form of very small drops. These small drops form clouds, out of which rain can fall.

Precipitation (बारिश): Water from the atmosphere falling down on the land- or water surface. In India it is mostly rainfall, in other countries it might also be snow or hail.

Percolation (रिसना): Water movement downwards within the ground through pores, fractures and fissures, driven by gravity. This movement is the main process recharging the groundwater (see Chapter 2.3).

Water level (भूजल स्तर): The location in the underground where the groundwater surface is met, is called water level. This level can be measured in wells. The water level rises and falls, for example, after heavy rainfalls during monsoon or due to groundwater pumping.

Further reading:

- National Oceanic and Atmospheric Administration (NOAA): http://www.nws.noaa.gov/om/hod/SHManual/SHMan014_glossary.htm

Interactive tool: Water-Cycle-Sheet and Water-Cycle-Wristband

To consolidate the knowledge of the water cycle, two interactive parts have been developed and can be used during the workshop while explaining the water cycle.

<u>The Water-Cycle-Sheet</u>

1) *Preparation.* Make sufficient color printouts (one for every participant) of the Water-Cycle-Sheet (Annex A1) and black-white printouts of the corresponding document with the Hindi Terms for the Cycle (Annex A2). Provide enough glue sticks and scissors (one of both for every 4-5 participants).
2) Distribute the printouts (Water-Cycle-Sheet) among the participants and ask them to assign the right term (Water-Cycle-Hindi Terms) to the associated process on the cycle sheet (do not glue them yet).
3) After 5-10 minutes, let one or two of them explain how they think the water cycle works.
4) Show the solution on the screen and explain the single steps of the water cycle.
5) Now you can ask the participants to glue the terms on the correct place.
6) The participants can take the sheet home to show it to their family/friends.

<u>The Water-Cycle-Wristband</u>

1) *Preparation.* Buy a long yellow string, which will be used to represent solar energy (minimum 6 m). Buy beads of the following colors: light blue (evaporation), green (representing transpiration), white (condensation), dark blue (precipitation), brown (infiltration). Of every bead-color, buy at least as many as the number of your participants.
2) Distribute the string, the beads and some scissors among the participants.
3) Ask the participant to tie a wristband for their neighbor in the order of the hydrological cycle: light blue – green – white – dark blue – brown. Explain to them that the yellow band represents the solar energy which is the motor of the whole cycle. The colored beads represent the respective processes (see step 1).
4) Let the participants repeat the processes of hydrological cycle and ask them to check if their wristbands are correct.

5) The participants can take the wristbands home to show it to their family/friends and to remember/internalize the cycle over the next days/weeks.

Supporting material: PowerPoint presentation and sheets

Name: WaterWorkshop_Session2_Groundwater
Pages: 6-7

Annex A1: The Water Cycle

Annex A2: The Water Cycle – Hindi Terms

2.3 Groundwater

In the previous section (2.2), groundwater was introduced as one part of the hydrological cycle. In the following section, it will be discussed why it is important to know more about groundwater and the most important terms and concepts of groundwater will be introduced.

2.3.1 Why it is Essential to Know More About Groundwater

There are numerous reasons to use groundwater for water supply (in comparison with surface water):

- you can find it nearly everywhere
- normally, it is there throughout the year → resource for drought seasons
- it can be cleaner than most surface water sources
- lower costs than tanker water

But:

- Many quality and quantity problems → huge impact on daily live, health, time, infrastructure

2.3.2 Important Terms and Concepts

Hydrogeology: "Hydro" means water and geology is the science of the earth/rocks/ underground. Therefore, hydrogeology deals with the water in the underground and looks at its formation, distribution, movement and inter-action with soil and rocks. The soil and rocks vary from place to place and thus, the water characteristics will vary, too.

Groundwater: Water found underground in the pore spaces, cracks and fractures in soil, sediment and rock, where it moves due to gravity.

The **water table** marks the border between the **saturated** and the **unsaturated zone**. In the **saturated zone** the pores/fractures in the soil/rock are completely filled with water. In the **unsaturated zone** the pores/fractures in the soil/rock are partially filled with water and partially with air.

Aquifer: Permeable layer of rock or sediment in the underground which is able to store and to transmit water. Good aquifers are usually developed in sands, gravels, weathered limestones and fractured sandstones (Hiscock 2005).

Aquitard: Layer with low permeability in the underground. Aquitards include clay layers, sedimentary and magmatic rocks without fractures. These rocks or sediments can store water to a certain degree, but the very slow movement of the groundwater in these rocks does not allow an extraction of water with wells.

Aquifers can be **confined** or **unconfined**. A confined aquifer is overlain by an aquitard (low-permeable

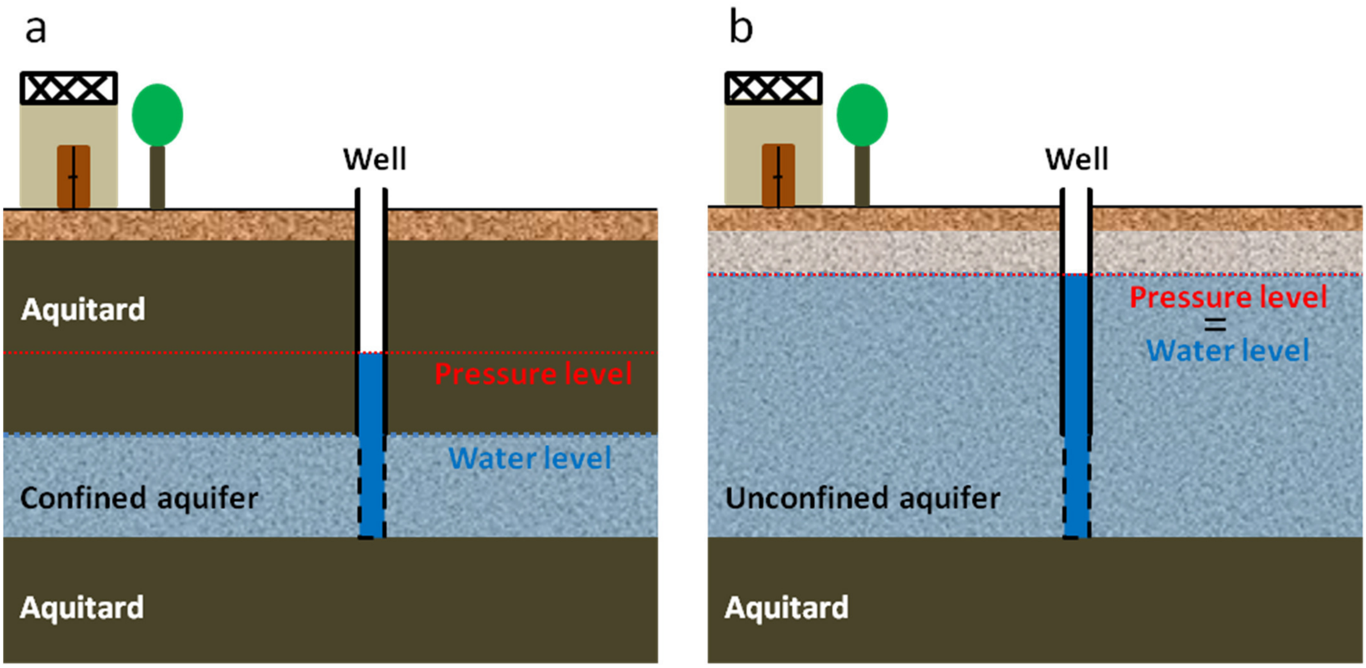


Figure 7: Simplified schematic of a confined (a) and an unconfined aquifer (b) with related water level in the well.

layer) and the pressure level lies above the water table. If you dig a well into a confined aquifer the water level in the well will rise and will be higher than at top of the aquifer due to the pressure release (Fig. 7a). An unconfined aquifer has a "free water surface", meaning that the groundwater surface can rise and fall as a direct response to recharge and discharge. The water level is at the same time the pressure level (Fig. 7b).

At most places you can find **shallow** and **deep aquifers**. Their various characteristics are shown in Table 1.

Recharge and **discharge areas** are important regional hydrogeological areas. Recharge areas are typically areas of higher elevation and, usually, little urban development, where the hydrogeological condition for groundwater recharge is excellent. Discharge areas are mostly found in low lying areas, where water from the underground is released to the

Table 1: Characteristics of shallow and deep groundwater.

	risk of manmade contamination	recharge process	exploration costs	risk of running dry	type of wells	typical depth [m]
shallow	high	fast (weeks to years)	low	high	hand pumps; dug wells	5-30
deep	low	slow (years to decades)	high	low	bore wells	50-200

Table 2: Characteristics of recharge and discharge areas.

	groundwater-quantity	vertical groundwater movement	depth to water	suitability for groundwater abstraction	suitability for artificial groundwater recharge
recharge area	replenishing	downwards	deep	low	high
transit area	replenishing/constant	parallel to topography	intermediate	medium-high	medium
discharge area	depleting	upwards	shallow	high	low

surface, e.g. groundwater infiltrating into a river. The intermediate area between recharge area and discharge area is called transit area. Here the groundwater flow is almost parallel to the topographic gradient (Tab. 2).

The catchment area defines a basin where water gets collected when it rains and which is often bounded by hills. The highest points of the hills define the border to the neighboring catchment area. The collected rainfall flows from the elevated hills to the lower parts of the basin where it often cumulates in rivers or lakes. Rivers transport the collected water following the topographic gradient. The same process applies to groundwater when rainwater infiltrates and flows along the gradient from highest areas of the basin (with the highest pressure levels) to the lowest areas of the basin (with the lowest pressure levels) (see Fig. 8). Catchment areas can be defined on different scales: local, regional and supraregional. For example, a supraregional catchment can be subdivided in numerous regional and local sub-basins. Under most conditions, the surface water catchment area can be used to define the groundwater catchment area as a first approximation. Beware when you are working in limestone areas, where karstic aquifers occur and in areas with complex geological and tectonic conditions. Under those conditions surface water and groundwater catchments might be completely different.

Surface runoff occurs if the water/rain cannot infiltrate because the soil is saturated or the surface is impermeable, which is often the case in sealed urban areas. During intensive rainfalls, e.g. during

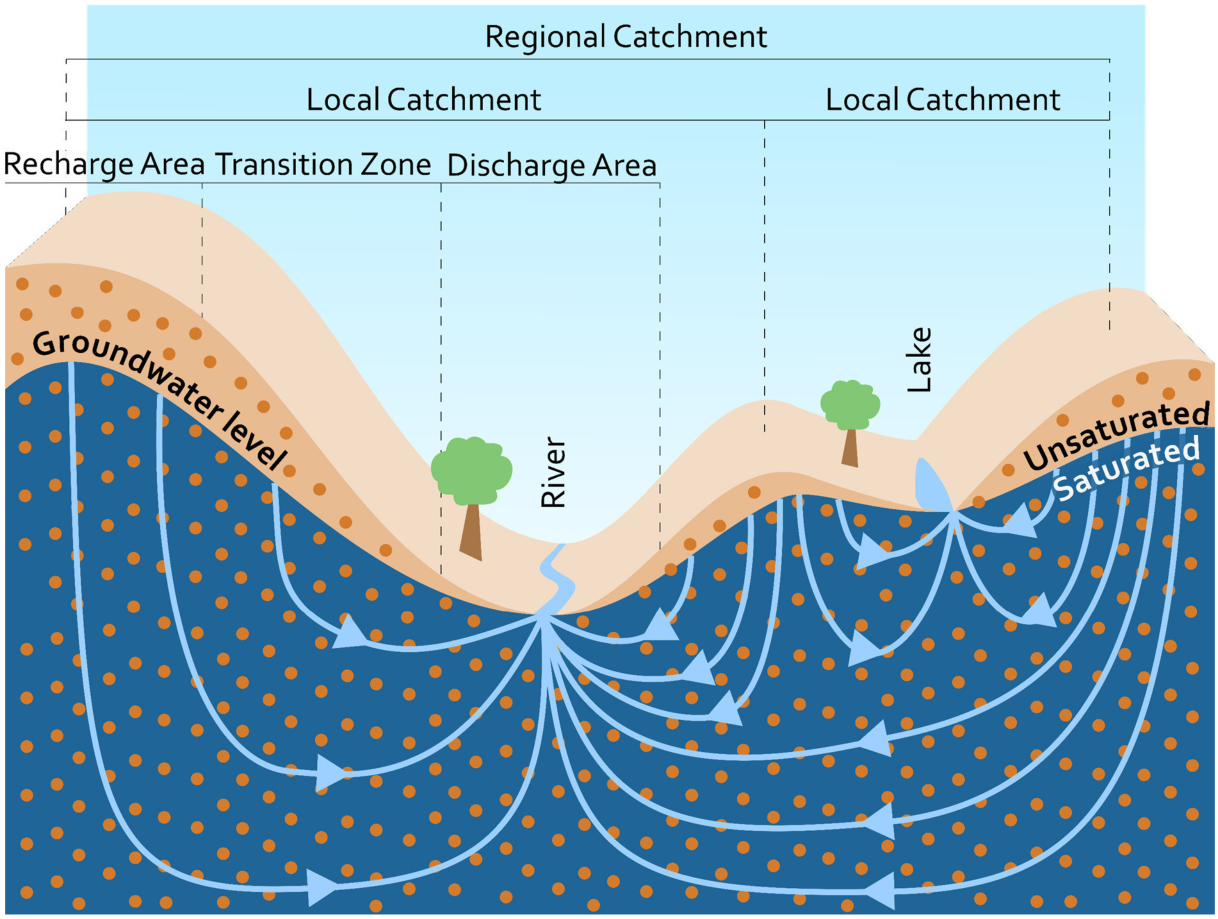


Figure 8: Schematic of regional and local groundwater flow systems

monsoon season, high surface runoff rates can cause severe damage for people and houses.

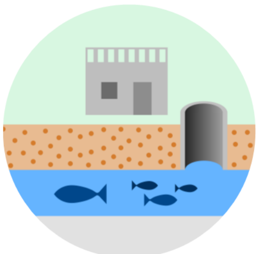
Safe yield describes the amount of water which can be withdrawn from a groundwater basin annually without producing an undesired result. Any draft in excess of safe yield is overdraft (Todd 1952).

Well yield describes the amount of water which can be abstracted from a well without lowering the water level below the pump intake (Wilson and Moore 1998).

Further Reading:

- British Geological Service: http://www.bgs.ac.uk/research/groundwater/resources/glossary.html
- IGRAC (International Groundwater Resources Assessment Centre): https://www.un-igrac.org/groundwater-glossary
- The Groundwater Foundation: http://www.groundwater.org/get-informed/basics/groundwater.html

2.3.3 Typical Misconceptions

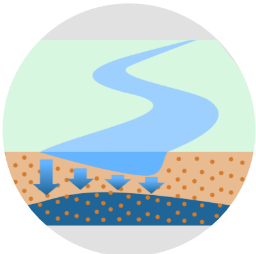


There is an underground lake or river → Not correct!

Groundwater exists within the pores of the soil and the fractures of rocks. It can be distinguished between sediments/rocks with high permeability (for example: sand, gravel, sandstones with fractures, karstified limestones) and sediments/rocks with very low permeability (e.g. clay, massive rocks without fractures)

Groundwater is static → Not correct!

Groundwater is moving following a gradient, like surface water is also moving, but the movement of groundwater is much slower. But also the abstraction (pumping) and local recharge (rainfall) can cause the movement of groundwater and a change in groundwater levels.



Groundwater and surface water have nothing in common → Not correct!

Groundwater and surface water are influencing each other: Surface water infiltrates into the ground recharging groundwater and at the same time groundwater can feed rivers and lakes.

Clear water is safe → Not correct!

There can be a lot of invisible contaminants, like E. coli bacteria and fluoride, for example. Sometimes, very small amounts of contaminants, way too small to see, can be enough to cause serious health problems

Groundwater is unlimited→ Not correct!

Wells can run dry when the amount of water abstracted is higher than the groundwater recharge (see Section 2.3.4).

2.3.4 Groundwater Quantity in Urban Low – Income Areas in India

In the previous chapter (2.3.3) it was said that groundwater is limited. But how can it happen that the well in a community runs dry? In this chapter, two examples are given. In the first example, water scarcity occurs due to the impacts of climate change whereas in the second example water scarcity is caused by an overuse of the groundwater resources, which can be the result, for example, of population growth.

Scenario 1: The absence of monsoon rainfall can influence groundwater levels on a regional scale. Figure 9a displays the normal situation with regular rainfall. Both, the deep borewell as well as the shallow hand pump are giving a sufficient amount of water. Figure 9b displays the situation after no or much less rainfall occurred during the monsoon season. The groundwater levels are declining. The shallow hand pump runs dry. Figure 9c depicts the situation after several years of discontinuous

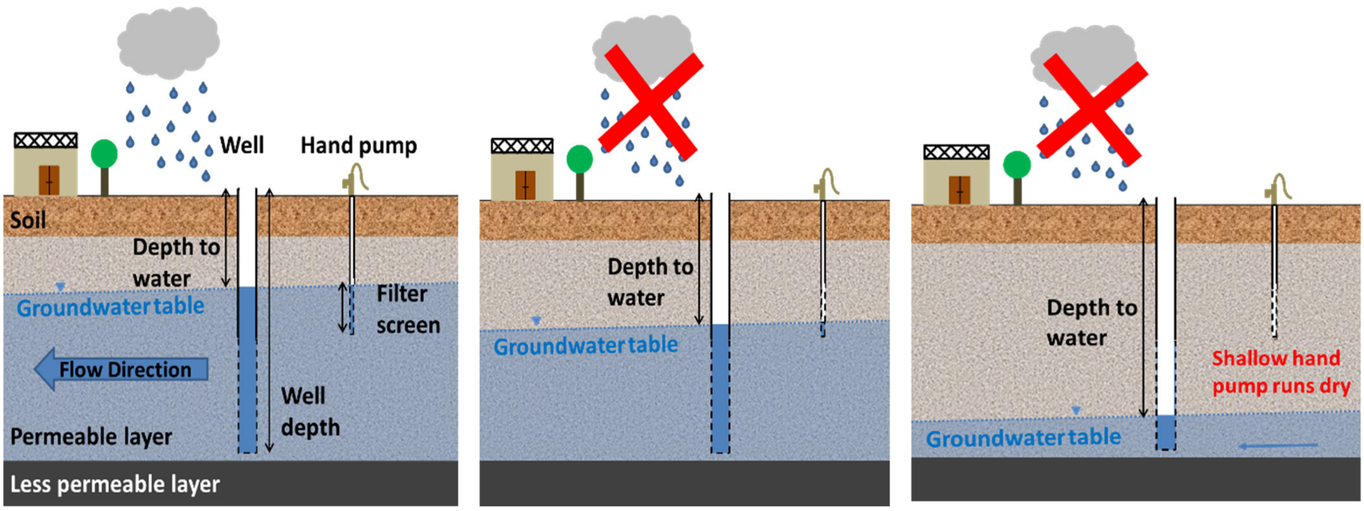


Figure 9: Scenario1: Groundwater table depletion due to missing rainfall.

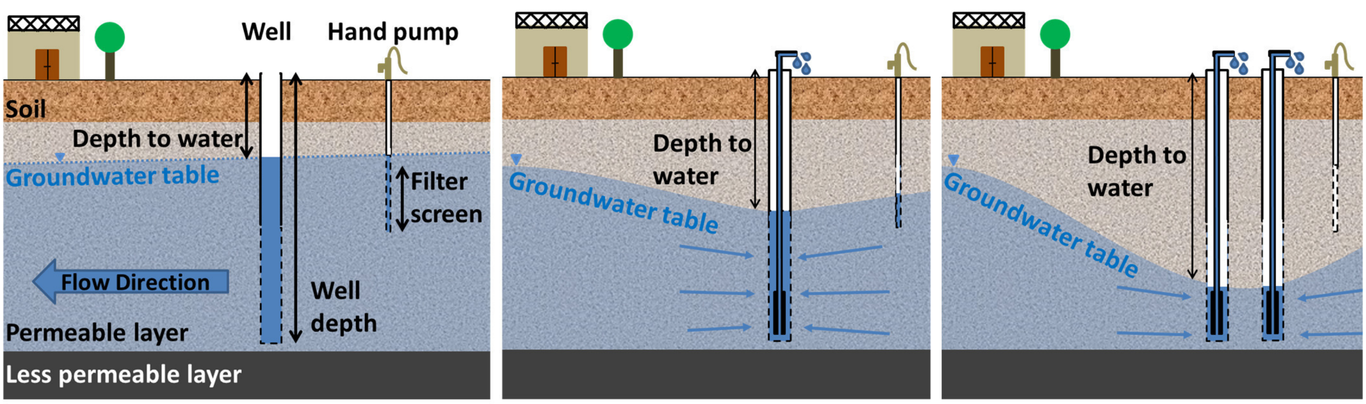


Figure 10: Scenario 2: Groundwater depletion due to new bore wells.

monsoonal rainfall. As a result, the yield of the deep borewell can decrease significantly.

Scenario 2: The second scenario illustrates a situation which occurs on a local scale. As in the first scenario, a deep borewell and a shallow hand pump are shown (see Fig. 10). In contrast to it, the rainfall in the second scenario is continuous but the exploitation of the groundwater resource increases. Figure 10a depicts the situation after the construction of a new borewell which is not yet operating. The groundwater flow follows the natural gradient (driven by gravity) and the groundwater table is plain. The hand pump is giving a sufficient amount of water. In Figure 10b, the borewell started to operate. The withdrawal of groundwater produces a local decrease of the groundwater table forming a cone-shaped depression of the groundwater table with its deepest point at the borewell. For all hand pumps which are situated within this cone of depression, the water table is declining and the yield might diminish. The flow direction in the cone of depression is towards the borewell and the natural flow direction is locally disturbed. Figure 10c shows the operation of two borewells. The increased groundwater abstraction from both wells produces a deeper cone of depression, causing the hand pump to run dry.

In the case where the groundwater abstraction by borewells overcomes the groundwater recharge by rainfall, a regional lowering of the groundwater table might occur, additionally to the local cones of depressions described in the second scenario.

2.3.5 Groundwater Quality in Urban Low – Income Areas in India

Typical contamination paths in urban low-income areas:

Open defecation

Open defecation harms the groundwater quality, because, in contrast to toilets connected to sewage systems, no treatment of the feces can take place. Feces infiltrate directly into the soil and then into the groundwater (Fig. 11), which can cause serious health problems.

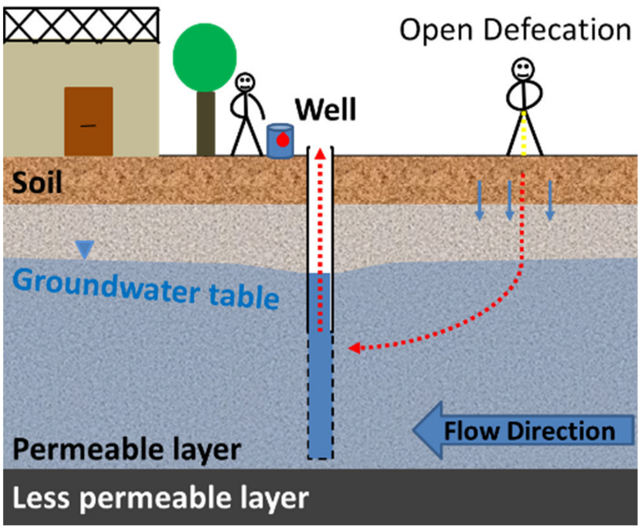


Figure 11: Typical contaminations paths in urban low-income areas: Open defecation.

Pit latrine

If pit latrines (local name: chambers) are not completely sealed against leaching, the accumulated feces seep into the soil and then into the groundwater. If a pit latrine is located up-gradient of a nearby well the contamination can travel with the groundwater to the well following the flow direction.

This can also happen if the pit latrine is within the area of influence of the pumping of a well, which changes the flow direction locally (see Fig. 12).

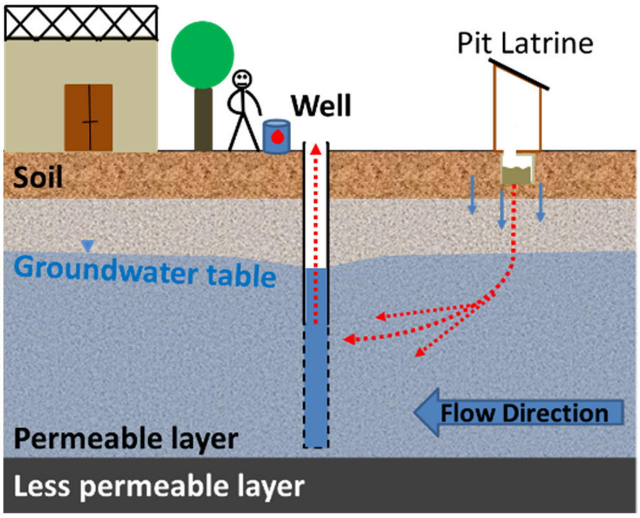


Figure 12: Typical contaminations paths in urban low-income areas: Pit latrine.

Solid Waste Disposal

Solid waste disposal also poses a serious risk to groundwater quality. Rainwater can leach toxic substances out of the waste and transport these substances into the soil and then into the groundwater (Fig. 13).

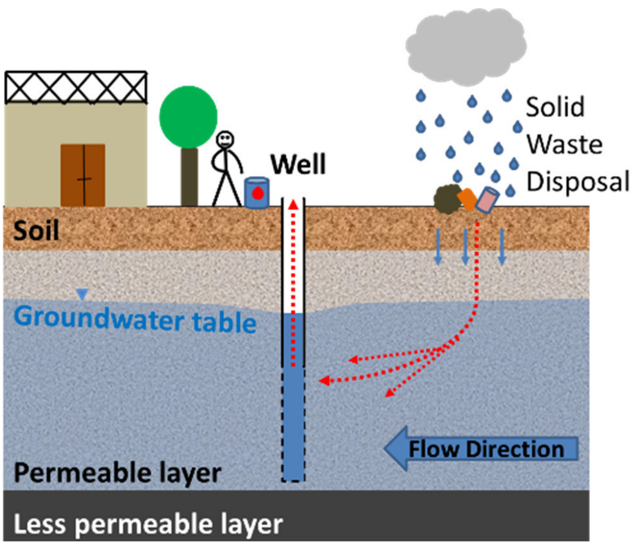


Figure 13: Typical contaminations paths in urban low-income areas: Solid waste disposal.

Water logging

Solid waste disposal in combination with water logging due to an accumulation of sewage or rainfall can lead to a transport of toxic substances into the soil and then into the groundwater (Fig. 14).

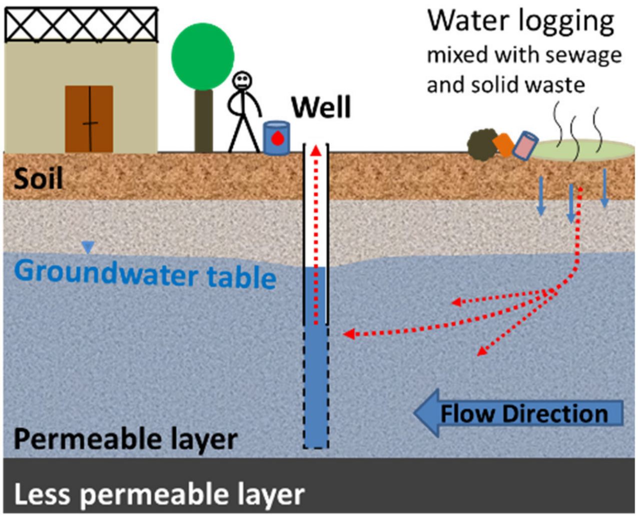


Figure 14: Typical contaminations paths in urban low-income areas: Water logging mixed with sewage and solid waste.

Direct contamination

If the well is not protected against contamination, such as animal dung or sewage, these substances can directly get into the groundwater through the well pipe (Fig. 15). This is a very fast and dangerous contamination pathway, as no filtration through the soil takes place and the contamination is immediately at the well.

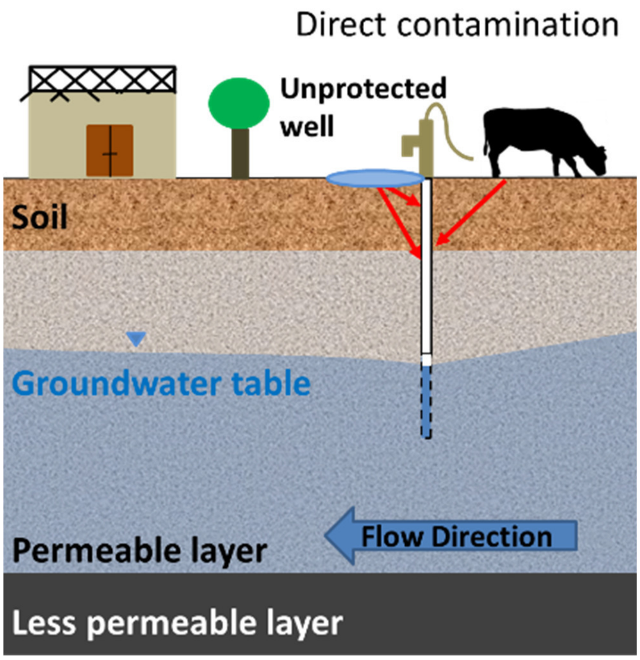


Figure 15: Typical contaminations paths in urban low-income areas: Direct contamination.

Interactive tool: Underground drawing, simplified groundwater model, dissolution of salt in water

Draw your imagination of the underground

After introducing the groundwater thematic and before explaining important terms and concepts of groundwater, the women should be asked to draw how they imagine the underground beneath their area. This will reveal the common understanding of groundwater among the participants to the workshop conductor which is helpful to prepare the following lessons.

1) *Preparation*. Make color printouts (one for every participant) of the Underground-Drawing-Sheet (Annex A3). Provide many different colored pencils.

2) Explain the sheet carefully, e.g. that the top is the surface and the rest should be filled by the participants in the way of a cross-section through the underground.

3) Ask the women to draw how they imagine the underground beneath their area. They can do this either alone or in small teams (2-3 women).

4) Let them draw for 10-15 minutes.

5) If you have enough time, ask the women to explain what they have drawn in front of the group. This can take up to one hour. Alternatively, let only one team explain its drawing.

6) Show the schematic exemplary cross-section at the screen and explain the different layers and the groundwater table.

7) Discuss the drawings of the women in terms of wrong and right beliefs/perceptions.

Simplified groundwater model

To explain in a demonstrative way how groundwater is stored in-between sand grains, gravel etc. (not building an underground lake or river) a simple groundwater model can be used:

1) *Preparation.* Cut a 1 or 2 L water bottle at the half and fill sand in the lower part of the bottle before the workshop.

2) Fill water into the sand-filled part in front of the participants.

3) Show it around and explain that water in the underground is stored in-between sediments and that there is nothing like a lake or river in the underground.

4) You can also prepare several bottles in order to make it easier to show it to all participants.

Dissolve salt in a glass of water

An easy way to show that apparently clear water can be contaminated is to dissolve salt in a glass of water.

1) *Preparation*. Get a glass, a spoon and salt.

2) Fill a glass with tap water in front of the participants.

3) Take a spoonful of salt and dissolve it in the water.

4) Show the women that you cannot see the salt anymore, but the water is salty now.

5) You can also let some of them taste the water before and after the dissolution of the salt.

6) Explain that there can be many invisible parameters which can be much more harmful than salt.

7) Conclude that clear water does not mean that the water is safe for drinking.

Supporting Material: PowerPoint presentation and sheets

Name: WaterWorkshop_Session2_Groundwater
Pages: 8-20

Annex A3: Underground Drawing Sheet

Hints and Tips

- Mind your words: many locals are not used to abstract. For example, if you explain how a soak pit can (!) contaminate a nearby well, they may be afraid that all their wells are contaminated.

3 OBSERVING – UNIT 2

Important water quantity and quality parameters and how to measure them.

With the previous chapter UNDERSTANDING (Unit 1), a basic awareness was built, constituting the first level of participation. The present chapter OBSERVING (Unit 2) aims at an active involvement, which forms the next level of participation. This can be time-intensive and requires a certain level of understanding, therefore, this work should be done with a smaller number of women. A good option is to work with two women per community, of whom one should be able to read and write. It is recommended that one of the women is a younger woman or a girl in order to include the future generation.

This chapter is structured into three parts, starting with the preparatory mapping of the water infrastructure of the area. The following two parts demonstrate methods of measuring the water quantity and the water quality.

Definition of terms used in this chapter:

- Local water points: Local water points include all sources of water used for the water supply (waterlines, bore wells, dug wells, hand pumps, step wells, surface water bodies) as well as existing water bodies (nallahs, talabs) and wells which are not used for the water supply and therefore can serve as piezometer (see Chapter 5).
- Monitoring points: Monitoring points include the local water points chosen for a regular monitoring.
- Local women assistants: The 2-3 women from the community which will do the mapping and testing and will be involved in this project on a permanent basis.

3.1 Mapping the Water Infrastructure

Before starting with the water testing, the water infrastructure of the area has to be mapped for a number of reasons:

- to get an overview of the water supply system of the community
- to quantify the different water sources (e.g. groundwater, tanker water, waterline)
- to be able to make a reasonable decision where to take samples

The first one or two days, the mapping should be conducted under guidance of the executing organization. When the local women assistants are familiar with the procedure they should do the work by themselves.

Location

All wells (bore wells, hand pumps, dug wells, step wells), surface water bodies (nallahs, talabs, lakes and rivers), and waterline connections (public/private, legal/illegal) should be mapped. Depending on the size of the area and the kind of water supply infrastructure it will take 1-2 weeks.

Material

Clipboard, GPS, pen, mapping sheets (Annex A4, A5), area map (if available)

Procedure

1) Define the borders of the area of interest.

2) All local water points in the area of interest need a unique ID. If they have a name already, this name should be used. If a local water point does not have a name, the following system can be applied: A short (2-3 letter) identifier for the area – an abbreviation for the type of sampling point (HP: hand pump, DW: dug well, ...) – a consecutive number. Example: NKT-HP-01 (first hand pump mapped in the area Nai Ki Thari).

Figure 16: Neetu from Khara Kuaa during the mapping, Jaipur 2016.

3) GPS: Take a GPS point with your GPS device (Fig. 16) to identify the exact coordinates of the location (longitude (X), latitude (Y) and elevation (Z)). If you do not have a GPS device, you can also use the GPS function of your mobile phone. If a map of the area is available, you should use it to mark the location of the local water point directly on the map.

4) Note down a nearby landmark (e.g. the name of a nearby temple or mosque, any kind of shop, a big tree). Later, it may help you or others to remember the local water point (and its location).

5) Wells: Interview the well owner (or community members in case the well or hand pump was built by public institutions, NGOs etc.) about the well characteristics, for what purpose they use the water and if they use any kind of filter (e.g. RO machine). Describe the condition of the well (see Annex A4):

   a. Characteristics
      i. Built by
      ii. Well depth
      iii. Diameter of well

iv. Depth and length of filter screen*

b. Use
   i. Drinking
   ii. Irrigation
   iii. Industrial
   iv. Household

   i. Private
   ii. Public

c. Condition
   i. Protected, e.g. fence around well and concrete sealing
   ii. Unprotected, e.g. free access to the well and its surrounding, missing sealing of the ground
   iii. Partly protected, e.g. concrete sealing at hand pumps

6) Waterline connection: Interview the owner about the connection, for what purpose they use the water, related supply times and if they use any kind of filter (e.g. RO machine) (see Annex A5):

a. Connection
   i. Tap
   ii. Open
   iii. Bolt

b. Use
   i. Drinking
   ii. Irrigation
   iii. Industrial
   iv. Household

   i. Private
   ii. Public

c. Supply times

7) Decide if this local water point is suitable as a monitoring point:

a. Owner agreed
b. Many people using it
c. Easily accessible
d. Groundwater available (wells)
e. Regular water supply (waterlines)

See Section 3.3 for detailed explanation of each point.

8) Note down any observation you have made (e.g. private pumping machine is connected to the waterline; tap is leaky).

9) Take 2 photos: One close-up view of the local water point itself and one overview of the local water point within its surrounding.

10) The implementing organizations should plot the GPS coordinates of the local water points with the respective unique IDs on an area map. This can be done either by google earth or by the open and free GIS software QGIS (see supporting material).

11) Make a printout of the map with the local water points. You will need this map for the next steps (see Section 3.2 and 3.3).

Supporting Material:

Annex A4,5: Water Infrastructure – Mapping Sheets

QGIS Tutorials:

1) http://www.qgistutorials.com/en/

2) https://docs.qgis.org/2.2/en/docs/training_manual/

* **Note:** The well construction may differ from place to place. You should talk to local drilling companies to get to know the typical well design in the area of interest. In Jaipur for example, many wells are constructed without any filter screen but with plain iron pipes. The last 10-20 feet of the boring remains

open without any casing. In this case, you should note down the depth of the end of the casing.

3.2 Measuring the Water Quantity

Location

Based on the field mapping, choose all important local water points to monitor the (ground)water quantity. Following criteria can help you select monitoring points for your monitoring network:

- Accessibility: Is the local water point easily accessible, also during monsoon season? If it is a private local water point be sure that the well owner agrees with a regular measuring.
- Distribution: The monitoring points should be well distributed over the community in order to cover the area as best as possible.
- Diversity: Different local water points (e.g. surface water, groundwater) in the area should be measured regularly in order to understand the dynamics and the interaction between the different water sources.

3.2.1 Groundwater

The regular monitoring of the groundwater level can provide a lot of information:

- The groundwater flow direction can be determined. This is important to decide on the location for new wells, new sanitation facilities or artificial recharge structures, to identify the origin and spread of groundwater contamination or to implement groundwater protection measures.
- Short-term (seasonal) and long-term water level fluctuations can be determined, from which information about groundwater availability can be derived.
- The impact of newly constructed recharge structures can be observed.

Unequipped wells that are not affected by pumping of any nearby wells are the best places for groundwater level measurements as they most closely represent natural conditions. Therefore, piezometers (see Fig. 17a) constructed under such considerations would be the ideal points for a monitoring network. However, only a limited number (if any) of piezometers will probably exist in your area of interest. In practice, most wells are equipped with a pump. Therefore, it is best to use abandoned dug wells and broken hand pumps (see Fig. 17b) to determine the groundwater levels. Information about the depth of the casing and filter screens is very useful. Make sure that you have informed the owner, most times it is the local water supplier, about your work at the hand pumps.

Figure 17: a) left side: piezometer; b) right side: opening a broken hand pump with spanners.

Material

Measurement sheet (Annex A7), pen, self-built water level meter (Annex A6)

Procedure

Determine the well depth (only once at the beginning):

1) Ask the well owner or the responsible authority (e.g. water supplier, groundwater board) about the depth of the well and of the filter screen (if there is one) and/or use the self-built water level meter (Annex A6) to measure the well depth (if you have not done this already during the mapping). This information is helpful to determine which aquifer is tapped. It can also give you a hint about the risk of the well running dry (in dry years or due to over abstraction) or the risk of groundwater contamination (see Tab. 1 in Section 2.3.2). If the well is equipped with a pump, ask at which depth the pump is installed (see Fig. 18).

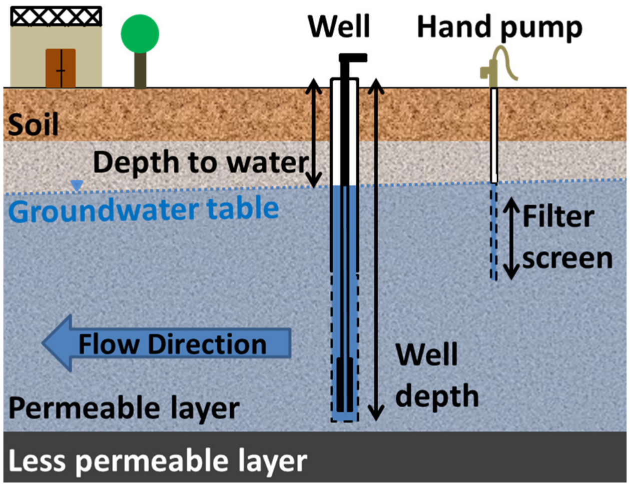


Figure 18: Simplified schematic of a well equipped with a pump and a hand pump tapping an unconfined aquifer.

Note: The well construction may differ from place to place. You should talk to local drilling companies to get to know the typical well design in the area of interest. In Jaipur for example, many wells are constructed without any filter screen but with plain iron pipes. The last 10-20 feet of the boring remains open without any casing.

Depth to water measurements (on a regular basis):

2) Decide, together with the local women assistants, on a regular time interval. A sampling every two months is a good option, if you want to be able to detect seasonal changes. The minimum interval should be twice a year: pre monsoon (e.g. in May) and post monsoon (e.g. in October).

3) Conduct all depth to water measurements on one day. This is important to be able to compare the measurements from different wells.

4) At each well, define (and best: mark) one point from where you always will do the measurement, e.g. at a bore well the top of the casing (see Fig. 19). This fixed reference point is important to make the measurement taken over time from the same well comparable.

5) Step by step instructions are given in Annex A6.

6) Note down the result on the measurement sheet (see Annex A7).

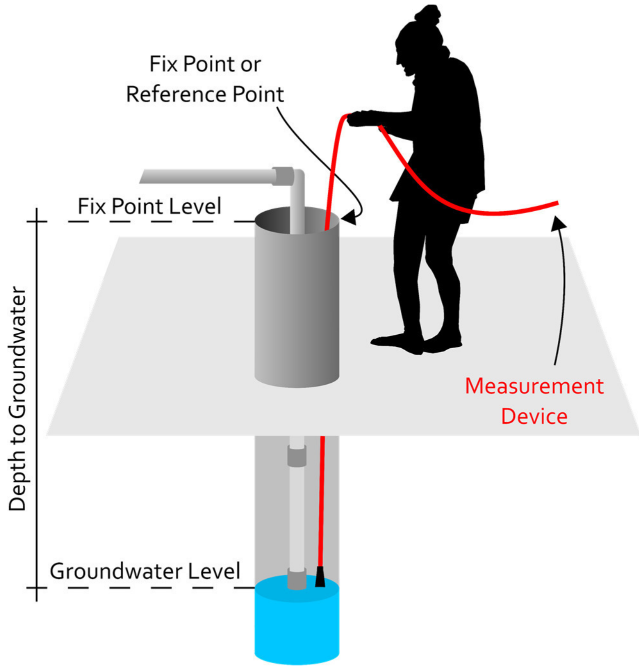


Figure 19: How to measure the depth to water.

3.2.2 Surface Water

Monitoring the water levels of surface water bodies can give you first information about the correlation with rainfall (during monsoon) and evaporation (during summer) and how the surface water is connected to the groundwater. In many urban communities, surface water bodies do not exist anymore because they were filled to be used as construction land or landfills. However, if there are lakes or nallahs in the community or nearby, a regular monitoring of their water level can be a useful hint for coming inundation or water scarcity.

Material

Measurement sheet (Annex A8), pen, water gauge

Procedure

1) Decide, together with the local women assistants, on the location for the surface water level monitoring.
2) Decide on a regular measurement interval (e.g. every two months).
3) Install a water gauge (see Fig. 20) at an easy accessible and protected place.

Figure 20: Example of a water gauge.

4) Read the water level from the water gauge at the fixed time intervals.
5) Note down the result on the measurement sheet (see Annex A8).

3.2.3 Piped Water

Given the case that the water supply of the community is based not only on groundwater and surface water but also on piped water, this supply part should be included into the monitoring plan. Data about the water actually supplied to the community can be helpful when demanding an improved supply scheme from the responsible authorities.

Choose at least two points to measure the quantity of water supplied. If the area is flat, take one point at the place where the main waterline is entering your community and the second point in the middle or the end of the supply line at an individual connection (to make it more convenient the women can use their own connection for the monitoring). If the area is hilly, decide on one measuring point at a lower and a second point at a higher elevation. Often, the supply in area of higher elevation is less, so be sure that your network is covering the whole range.

Material

Stopwatch (mobile phone), measuring jug (1-10 L), measurement sheet (Annex A9), pen

Procedure

1) Decide on a regular measuring interval (e.g. once a week)
2) Do it, if possible, always to the same time (e.g. 8am).
3) Note down the time, when the water supply starts.
4) Fill your measuring jug while stopping the time.
5) Note down the time it took to fill your measuring jug.
6) Calculate the flow rate: volume of the measuring jug divided by the filling time.

Example: 2L jug, 50 seconds filling time

1. 2 L / 50 s = 0.04 L/s
2. 0,04 L/s * 60 s = 2.4 L/min

7) Calculate the total amount of water: Flowrate times flow time.
   Example:2.4 L/min flowrate, 70 min water flow
   1. 2.4 L/min * 70 min = 168 L

8) Note down the result on the measurement sheet (see Annex A9).

3.3 Testing the Water Quality

The quality of the groundwater used by the community should be subject to a regular monitoring in order to determine current quality problems and to detect possible changes in time.

To do so, a cost-effective and reliable water testing equipment is needed. It should have a clear step-by-step manual enabling non-scientists to conduct the testing by themselves. Furthermore, is should provide the possibility to test various parameters.

Within this project the Jal TARA Water Testing Kit produced by Development Alternatives, an Indian organization based in Delhi, proved to be a good option. It gives the possibility to test the following parameters:

- Physicochemical: pH, temperature, turbidity
- Chemical: arsenic, fluoride, ammonia, nitrate, iron, hardness, chloride, dissolved oxygen, phosphorous, residual chlorine
- Biological: coliform bacteria, benthic diversity

You can select the parameters necessary for your purpose and get a kit tailored to your needs. An 11-parameter-kit with tests for approximately 100 water samples (except for coliform bacteria: 10 analysis) costs about Rs. 7000-8000 (~100€).

Selection of parameters

It is advisable to choose as few parameters as possible for the regular testing to take into account the time restrictions from the local women assistants. But at the same time it is very important to cover the most important parameters. A common approach for a new area with unknown water composition is to start with a wide range of parameters. After the first measurements the range of parameters can be adjusted based on the results, i.e. if a parameter remains below detection limit (or remains within the requirements of the Indian standard drinking water specifications) it can be excluded from the further monitoring.

Table 3: Selection of parameters for different water sources.

Parameter	Groundwater	Surface water	Piped water
Color	✓	✓	✓
Odor	✓	✓	✓
pH	✓	✓	✓
Turbidity	✓	✓	✓
Temperature	✓	✓	✓
TDS/EC	✓	✓	✓
Hardness	✓	✓	✓
Chloride	✓	✓	✓
Nitrate	✓	✓	✓
Dissolved oxygen	✓	✓	-
Ammonia	✓	✓	-
Iron	✓	-	-
Benthic diversity	-	✓	-
Phosphorous	-	✓	-
Residual chlorine	-	-	✓
Fluoride	*	-	-
Arsenic	*	-	-
Coliform bacteria	*	*	*
*✓: always; -: not necessary; * : sometimes (see text)*			

The following parameters should always be tested for all water samples (see Table 3):

- The *color* of drinking water should be clear. Be aware that you do not confuse color with turbidity. If you are not sure about it, you can filter the water and check it again. If the water is clear now, it was turbidity. If it is still colored, it is color.
- *Odor* can give you a first information about the quality and is a better evidence of water quality than turbidity.
- *pH* is an indicator for the acidity of water. The dimensionless values range from 1-14 with 7 indicating a neutral water. Water with a pH lower than 7 is acidic and water with a higher pH than 7 is alkaline. The pH value is of great importance in many hydrochemical processes. Therefore, it has always to be measured when taking a water sample.
- The same applies for *Temperature*. Its unit is °C (degree Celsius).
- *Turbidity* is caused by very fine sediments in water making it less clear. Its unit is NTU (Nephelometric Turbidity Units). It is not always a quality indicator, because a lot of contaminants are invisible. Often, turbidity in groundwater is caused by incorrect constructed or old wells, where fine particles from the aquifer are able to enter the well during pumping.
- *Total Dissolved Solids (TDS)* depends on the ion concentration in water (high ion concentration = high TDS value). The unit is mg/L. Some instruments measure electrical conductivity (EC) instead of TDS. The EC value is also dependent on the ion concentration in water and is given in µS/cm. As a rule of the thumb you can convert EC values into TDS values by multiplying them by 0.65.

  Example:

  1) EC value of a water sample: 1500 µS/cm
  2) 1500 * 0.65 = 975
  3) Resulting TDS value: 975 mg/L

  TDS or EC measurements can also be used as a quality indicator for the chemical analyses: If you have a high concentration of ions (e.g. nitrate, chloride) in your water, also the TDS/EC value should be high, as it is directly depending on the dissolved ion concentration. If you cannot observe this relationship, you can conclude that one of the measurement went wrong and you should repeat it.
- *Hardness* is the sum of the ions which can precipitate as "hard particles" from water: Calcium (Ca) and Magnesium (Mg). Concentrations above 200 mg/L may cause scale deposition in water tanks and pipes.
- *Chloride (Cl)* is a main parameter of water. As its taste threshold is comparatively low people recognize water with high chloride concentrations very fast as salty water. This decreases the acceptance as drinking water.
- *Nitrate (NO_3)* should always be part of a monitoring as it is a common contaminant in urban as well as agricultural areas in many parts of India. Nitrate is the oxidized form of nitrogen occurring only at high oxygen concentrations.

Additionally, the following parameters should be tested in groundwater:

- The concentration of *dissolved oxygen (DO)* in groundwater plays an important role for many hydrogeochemical processes and should always be included in the monitoring.
- *Ammonia (NH_3)* contamination is often caused by sewage discharge. Therefore, it should be

included into the monitoring as it can serve as an indicator for an anthropogenic (human-caused) contamination. Ammonia is a reduced form of nitrogen occurring only at low oxygen concentrations.

- If you have high *iron (Fe)* concentrations in your groundwater sample, it can be an indication that the yield of your well may decrease with time. This is caused by precipitation of iron particles or the growth of iron bacteria leading to a clogging of the well. Also iron is a redox sensitive parameter and its characteristics change with oxygen concentration in water.

The following parameters should be tested in surface water:

- *Benthic diversity* describes the variety of organisms living on the river bottom. Diversity measurements are an indicator for the water quality of a river as benthic organisms are highly sensitive to contamination.
- In most cases, *phosphorous (P)* is of more significance for surface water bodies than for groundwater. As an important nutrient, it can cause harmful bloom events of cyanobacteria in lakes or slow flowing rivers. In groundwater, it occurs as phosphate. It can be useful as an indicator for human-induced contamination.
- The concentration of *dissolved oxygen* in surface water is an important quality indicator as it controls most of the aquatic life in the water. Low dissolved oxygen levels indicate a contamination by sewage.
- *Ammonia* (see previous paragraph).

The following parameter should be additionally tested in piped water supply:

- *Residual chlorine* occurs in piped water as a result of an imperfect disinfection with chlorine. It does not occur in natural water.

Fluoride, arsenic and coliform bacteria often occur in high concentrations in the groundwater in India. Therefore, it is important to include all three parameters in your first sampling campaign:

- If the area is known for *fluoride (F)* and/or *arsenic (As)* contamination, include these parameters into your monitoring. Arsenic is a redox sensitive parameter; this means that its mobility is dependent on the oxygen concentration in the water.
- The biological parameter *coliform bacteria* is used to test for the microbial water quality. Its occurrence indicates a fecal pollution of the water. For the first sampling campaign, it should be included in the monitoring for all monitoring points. If no occurrence is detected, for the following sampling campaigns the testing can be reduced to places and times where the contamination risk is high, e.g. during and after monsoon, near septic tanks.

<u>Location</u>

Based on the results from the mapping, the monitoring points should be chosen together with the local women assistants. The following criteria have to be considered:

- The best option is to have monitoring points where it is possible to measure both, water quantity and quality. However, in practice this is not always possible.
- Accessibility: Is the monitoring point easy accessible, also during monsoon season? If it is a private local water point be sure that the owner agrees with a regular sampling.

- Usage: The local water point should be used by many people. In most cases, it will not be possible to monitor all water sources in a community, therefore, the most important wells should be included into the monitoring network.
- Distribution: The monitoring points should be well distributed over the community in order to cover the area as best as possible. If shallow and deep wells are present in your area take samples from both.
- Diversity: Covering different water sources (e.g. groundwater, piped water from the waterlines)
- Land use: Covering different locations (e.g. near industries, near agricultural areas)

Material

Water Testing Kit, sampling protocol (Annex A10), TDS Meter, tissues, wastewater bottle, garbage bag, mobile phone (stopwatch and calculator)

Procedure

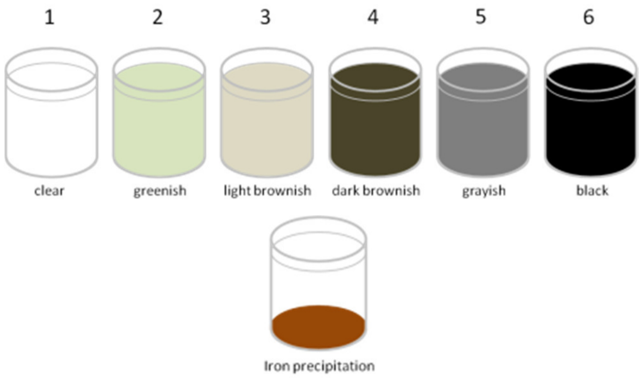
In the following section, only the general procedure will be described. The specific testing procedure for every single parameter is given in the water testing kit manual.

Preparatory steps:

1) Before you start the work with the local women assistants, be sure that you are familiar with the testing procedures.
2) Plan for a meeting with the women to teach them how to take a water sample with the kit. Choose a quiet place and plan for 2-3 hours.
3) During the first 2-3 sampling campaigns accompany the women. As soon as they are familiar and confident with the testing procedure let them do the sampling by themselves.
4) Emphasize the importance of working with great precision. Mistakes can happen, this is no problem. But discard any samples that you are unsure about.

Sampling steps:

1) Prepare the testing kit so that you are able to start with the tests as soon as you have taken the sample.
2) Fill out the first points on the sampling protocol, e.g. date, name of sampler, weather, time (see Annex A10).
3) Measure the air temperature.
4) Pump for some minutes before taking a sample (Annex 11).
5) Wash the sampling bottle two to three times with the sample water before you take the sample to be sure that no other water can influence the results.
6) Take the sample. Be sure, that you fill enough water in the sampling bottle/jug for all the tests you want to conduct.
7) Measure the water temperature.
8) Compare the color of the water sample with the example color given on the sampling protocol (see Annex A10). Do you observe red-brownish particles in the sample? This is precipitation of iron oxide which is an indicator that your groundwater is free of oxygen. When the groundwater comes in contact with oxygen in the well or during the sampling, the iron oxide precipitates.



9) Describe the odor of the water sample with the help of the examples given in the sampling protocol (see Annex A10).

Odor						
no	bleach (chlorine)	sulfurous (rotten eggs)	earthy/musty/fishy	gasoline/ fuel-like	sharp chemical	other:
	x					

10) Measure the TDS value with the TDS meter.

Figure 21: Zeenat and Tarnnum testing the water quality in their community, Nai Ki Thari, Jaipur 2017.

11) For the remaining parameters, follow the instructions given in the water testing kit manual. The analysis should be done in the order given in the sampling protocol (see Annex A10).

12) Describe the surrounding of the well e.g. if solid waste is laying around, if animals are there.

13) Note down any specific incidents, e.g. that one test was not working, that the well has run dry.

14) Note down the time, when you have finished the complete sampling.

Further Reading:

- Indian Standard Drinking Water -Specification: http://cgwb.gov.in/Documents/WQ-standards.pdf
- WHO Drinking Water Guideline: http://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/

3.4 Hints and Tips

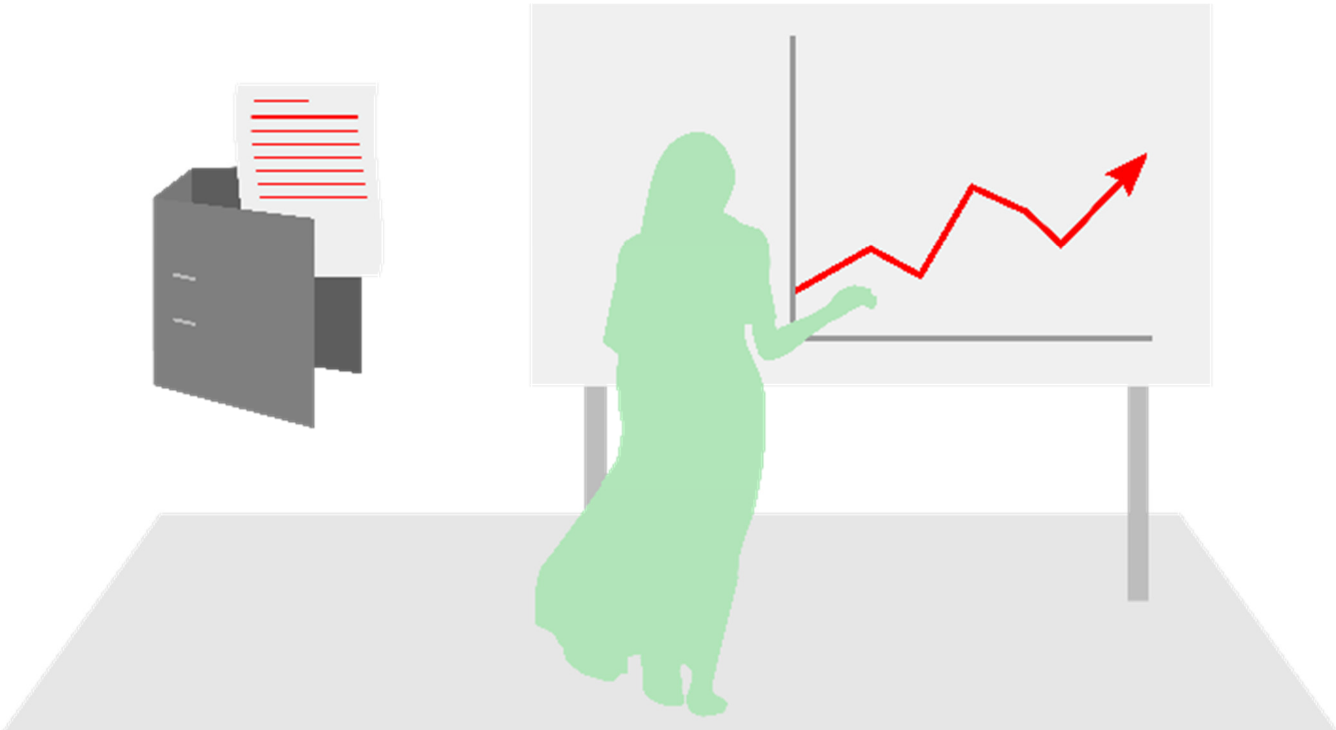
- Within this project it turned out that it is very advisable to always go to the field with the same auto-wallah. With an auto, you are able to transport the water sampling equipment easily and you can reach every monitoring point. The back of the auto can be used to conduct the tests (see Fig. 22).

Figure 22: The back of the autos as a mobile laboratory: Rekha and Neetu testing the water quality of their community, Khara Kuaa, Jaipur 2017.

- During the field work in Jaipur, the local women assistants were able to conduct the regular water sampling at four monitoring points.
- Do not mistake TDS for Electrical Conductivity (EC). If you are not sure, which you are measuring, check the manual of your device.
- Keep your kit clean. Clean the syringes and sample bottles after every sampling campaign.
- Clean the syringes from outside and inside with distilled water before inserting them into any chemical. If the distilled water delivered with the kit is empty, you can buy battery water from a petrol station (Rs. 40 per 1L bottle). Before you use it, check the TDS/EC value. It should be about 40 µS/sm.
- Clean the syringes from outside and inside with sample water before inserting them into the sample bottle. Wash the cylinders 2-3 times from inside with sample water before transferring the sample water into it.
- Clean the thermometer, the TDS meter and any other instrument from outside with sample water before inserting them into the sample water.
- When using the Jal Tara Kit:
    - Start (after measuring T, O_2, pH and TDS) with the fluoride test as it takes 1 hour waiting time.
    - When conducting the dissolved oxygen test, titrate slowly and carefully as the color change comes fast and abrupt.

4 DATA MANAGEMENT AND INTERPRETATION – UNIT 3

Why data management is important and how to implement it for water sampling campaigns: Simple ways to plot the data and to make a first assessment of the situation.



The active involvement part does not stop with data collecting but it continues with data evaluation and interpretation. The local women assistants will be enabled to plot the data collected by them in a clear and simple way. This enhances the understanding of the collected data and is necessary for the following interpretation. Without a proper data management, the previous work will be more or less useless as it is not possible to make a sound conclusion on the basis of countless single data points. Furthermore, a good data management makes it possible for other users to understand and evaluate the data obtained by the local women assistants.

4.1 Water Quantity

This section will be revised after the related field work with the local women assistants has been finished.

<u>Determining Groundwater Flow Direction</u>

In order to get a first idea about the groundwater flow direction, three major steps have to be followed:

1) Choose at least three wells in the area where you want to determine the groundwater flow direction. The chosen wells should not be linearly arranged and they should not be close to each other. Make sure that the chosen wells tap the same aquifer. This can be done by comparing the borehole profiles of the wells. If you do not have any borehole profiles you can compare the well

depth, which should be similar for all wells if they tap the same aquifer.

2) Determine the surface elevation of each well with a GPS. Measure the depth to water in all wells at the same date. Make sure that the point where you measure the surface elevation of the well corresponds exactly to the point where you are reading the depth to water (see Fig. 19). This allows you to calculate the water table elevation (water table elevation = surface elevation of the well – depth to water).

   Example: surface elevation: 360 m; depth to water: 15 m

   1) 360 m – 15 m = 345 m

   2) Water table elevation = 345 m

3) Plot all wells on a map of the area and mark the water level of each well. In general, the groundwater flows from higher water levels to lower water levels. If you want to determine the exact direction of the groundwater flow you have to take into consideration the change of elevation between all wells, because groundwater flows in the direction of the maximum gradient (see further reading).

Further Reading:

- Determination of groundwater flow direction: http://imnh.isu.edu/digitalatlas/hydr/concepts/gwater/gwflow.htm

4.2 Water Quality

Groundwater quality can change over time due to many reasons:

- Change in rainfall pattern can lead to a change in groundwater recharge. This affects the groundwater volume inducing changes in dilution, dissolution and transport processes in groundwater (e.g. of minerals, contaminants).
- Construction of new wells can lead to a lowering of the water table and, if not constructed correctly, can serve as a pathway for pollutants (see Fig. 15). The abstraction from new wells has an impact on the groundwater flow direction. Thus, pumping can cause the mobilization of groundwater from other areas/depths, causing a change in groundwater chemistry.
- Changes in land use are often associated with changes in the groundwater quality.

Material

Water quality record sheet (Annex A12), colored pens, filled sample protocols, pencil, rubber

Procedure

1) Make yourself familiar with the Water Quality Record Sheets before you start the assessment with the local women assistants.
2) Plan the first meeting only for explaining the Water Quality Record Sheets and teach how to work with them with the help of the examples given at the beginning. Explain the characteristics of each parameter, like source, health impact and drinking water limits:

pH: The health concern is negligible, but a high pH causes a bitter taste and water pipes etc. become encrusted; water with a low pH corrodes or dissolves metals and other substances. Both, natural and human actions influences the pH.

TDS (Total Dissolved Solids) is not of health concern at levels found in potable water, but the taste decreases with high TDS values and excessive scaling in water pipes etc. occurs. Sources are manifold: natural (geogenic) sources, sewage, urban and agricultural run-off and industrial wastewater.

Turbidity is not directly harmful for human health but it can provide food and shelter for pathogens which cause water-borne diseases. Many different components like clay, silt, finely divided inorganic and organic matter, algae and soluble colored organic compound can be the reasons for turbidity.

Dissolved oxygen in drinking water is not of any health concern. Its origin in groundwater is based on the contact with the atmosphere.

Fluoride can be a very harmful component for human health if it is consumed in excess. It causes dental fluorosis (tooth mottling) as well as skeletal fluorosis (bone deformation and painful brittle joints in older people). Salts and sedimentary fluoride-bearing minerals are the primary sources. However, contamination can also happen by dyeing and printing industries effluents.

Ammonium poses no health concerns for humans at low concentrations but it is toxic for aquatic species. Its sources are sewage discharge, industrial discharge and fertilizers.

Excessive *nitrate* intake can result in diarrhea or methaemoglobinaemia (blue-baby syndrome) in infants. Causes for nitrate in water are chemical fertilizers, animal matter, domestic effluents, sewage sludge disposal and industrial discharge.

Iron in water does not harm human health. Its limits are based on aesthetics rather than physiological effects. Iron concentration in groundwater is mainly caused by natural (geogenic) sources.

The health concern *of hardness* is negligible, but it can cause mineral buildup in plumbing, fixtures and water heaters. High concentration of hardness in water causes a poor performance of soaps and detergents. Its sources can be of natural origin, e.g. carbonatic rocks but also from industrial discharge and discharge from mines.

Chloride in water does not pose any significant health risks for humans, but it increases corrosivity. Its sources in groundwater can be human-induced (chemical industry discharge, sewage discharge, irrigation drainage) but it can also originate from natural (geogenic) sources.

Phosphate is not of health concern at levels found in drinking-water. The main source are sewage effluents, manure and fertilizer.

Bacterial contamination in drinking water is of significant health concern for humans. It can cause typhoid, dysentery, diarrhea and other water-borne diseases. Its main sources in groundwater are human and animal wastes.

No health-based guideline value is proposed for *color* in drinking-water. Color can be caused by the presence of organic matter, iron or other metals and by the influence of industrial effluents. The reason should be investigated, especially when a sudden change has taken place.

3) Let the women arrange the already filled sample protocols by date. (It makes the transferring of the data points to the record sheets easier.)

4) At the beginning, assign each of your monitoring points to one of the given colors on the sheets: Write the ID on the line behind the color and the "Kuaa" (English: well) – sign*.

   Example: ID = NKT_HP01

   1) कुआ 1:_______

   2) कुआ 1: NKT_HP01

**Kuaa was used as Hindi word for all monitoring points to make it easier for the local women assistants.*

Always use the same color for the same monitoring point, e.g. green color for NKT_HP01.

5) Now you can start transferring the results from the sampling protocols to the record sheets. On the y-axis you find the concentration of each parameter and on the x-axis you find the time.

6) With every new parameter, take enough time to explain again its characteristics. Repetition of the new information is important for the local women assistants to be able to keep it in mind.

7) The local women assistants should transfer the results to the Water Quality Record Sheet after every sampling campaign. This makes it possible to detect changes in time. Furthermore, an understanding of the range and rate of possible changes can be achieved.

4.3 Hints and Tips

1) Many local women assistants may not be used to work with coordinate systems, therefore, it is recommended to use a pencil for the first work with the record sheets. If the pencil marks are correct they can be colored afterwards. If they are wrong, they can be easily removed by a rubber.

2) Tell the local women assistants at the beginning that this is a long-term project and that you want them to work on it on a permanent basis. Also discuss with them how often the work is required. Repeat it several times. It is important that the women are aware of this so that they can decide if they want to be involved in the project.

3) After some months of ongoing work, the local women assistants are able to teach their newly gained knowledge and skills to women of other communities and also to NGO staff (see Fig. 23). In this way, the new knowledge will be consolidated and a sustainable capacity building will be achieved. Furthermore, it will increase the confidence of the women and make them proud of their ability to conduct water samplings by themselves.

Figure 23: Neetu and Rekha from Khara Kuaa explaining how to take a water sample to local NGO staff, Jaipur 2017.

5 Dictionary and Glossary

Alkalinity (क्षारीयता/ एल्केलिनिटी): A chemical parameter which is important to determine the ability of water to neutralize acidic pollution.

Aquifer (जलभृत): Porous soil or fissured rock underneath the land surface in which groundwater is stored.

Aquitard: Soil or rock which is too dense to store a significant amount of water and to transmit water in a significant amount and on a time scale appropriate for groundwater abstraction (for example clay).

Arid region (शुष्क क्षेत्र): A region where rainfall is so scarce that agriculture is only applicable with irrigation.

Confined aquifer (सीमित जलभृत): Groundwater that is tapped by a low-permeable layer, such as clay, so that the groundwater surface is under pressure.

Electrical conductivity (विद्युत चालकता): Water quality parameter which depends on the ion concentration in water (high ion concentration = high electrical conductivity).

Evaporation (वाष्पीकरण): Liquid water being transferred into vapor from bare surfaces.

Evapotranspiration (वाष्पन-उत्सर्जन): Liquid water being transferred into vapor from bare surfaces and plants.

Groundwater (भूजल): Water within the ground, stored in soil pores or rock fissures, which supplies wells and springs and which movement is due to gravity.

Groundwater table (भूजल की मेज): The depth at which groundwater starts underneath the land surface. It can vary due to water infiltration (rainfall) and water abstraction (pumping).

Hydrogeology (हाइड्रोज्योलोजी): A science branch combing Hydrology (water) and Geology (soil and rocks), therefore dealing with groundwater.

Infiltration (घुसपैठ): Movement of water downward through the soil surface into the soil.

Interception (अवरोधन): Water from rainfall which does not fall on the ground but is captured by vegetation.

Irrigation (सिंचाई): The controlled application of water to arable lands for agricultural needs.

Monitoring (...........................): Monitoring includes all activities which are necessary to observe and characterize certain processes and conditions, e.g. water quality, in a systematic way.

Piezometer (अवलोकन अच्छी तरह से): Well without pump, which is only used for water level and quality measurements (sometimes also called observation well).

Percolation (रिसना): Water moving downwards in the ground through pores and fissures, recharging the groundwater.

pH (पी. एच.): A chemical parameter: Water with a pH lower than 7 is acidic and water with a higher pH than 7 is alkaline.

Porosity (सरंध्रता): The space in soils between the grains or aggregates which is filled by water or air.

Precipitation (बारिश): Water from the atmosphere falling down on the land- or water surface (rainfall, snow, etc.)

Runoff (अपवाह): The water from rainfall that does not go directly into the groundwater, but flows towards the streams.

Safe yield (............................): The amount of water which can be withdrawn from a groundwater basin annually without producing an undesired result. Any draft in excess of safe yield is overdraft (Todd 1952).

Semi-arid region (अर्ध शुष्क क्षेत्र): A region in which slightly less rain is falling than water that is potentially evaporated by the sun (less dry than arid regions, drier than humid regions).

Solar Energy (सौर ऊर्जा): Energy in form of heat and light, coming from the sun.

Transpiration (भाप का निकलना): Liquid water being transferred into vapor from plants.

Turbidity (धुंधलापन/ टर्बिडिटी): Very fine sediments in water making it less clear.

Unconfined aquifer (असंबद्ध जलभृत): The ground-water surface can rise and fall freely within the ground without being stopped by an impermeable upper layer.

Vadose zone (वाडोस क्षेत्र): The soil or rock between the groundwater and the land surface, where pores and fissures are not completely water saturated but also filled with air.

Well yield (............................): The amount of water which can be abstracted from a well without lowering the water level below the pump intake (Wilson and Moore 1998).

6 Literature

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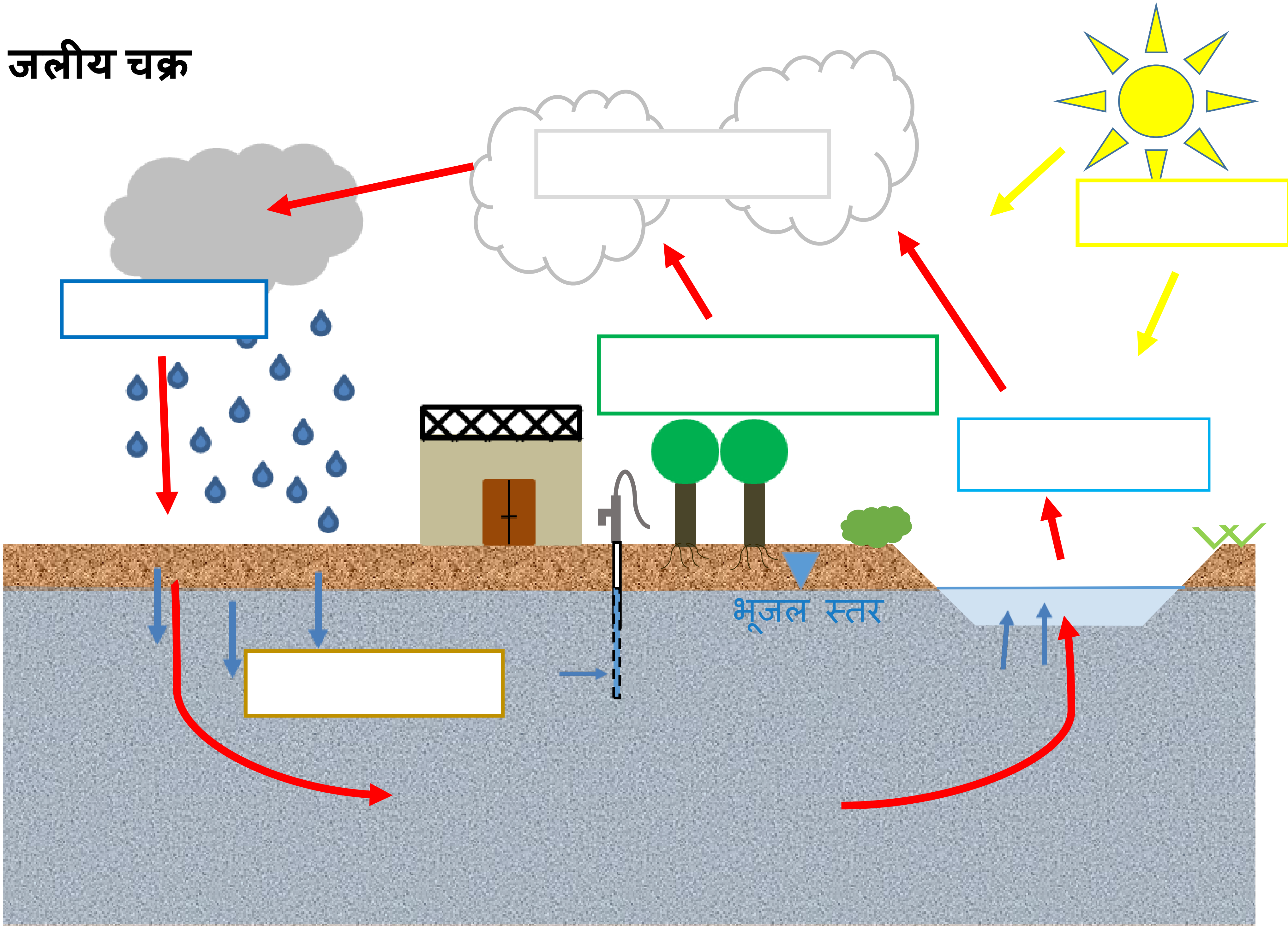
7 Annex

A1 The Water Cycle

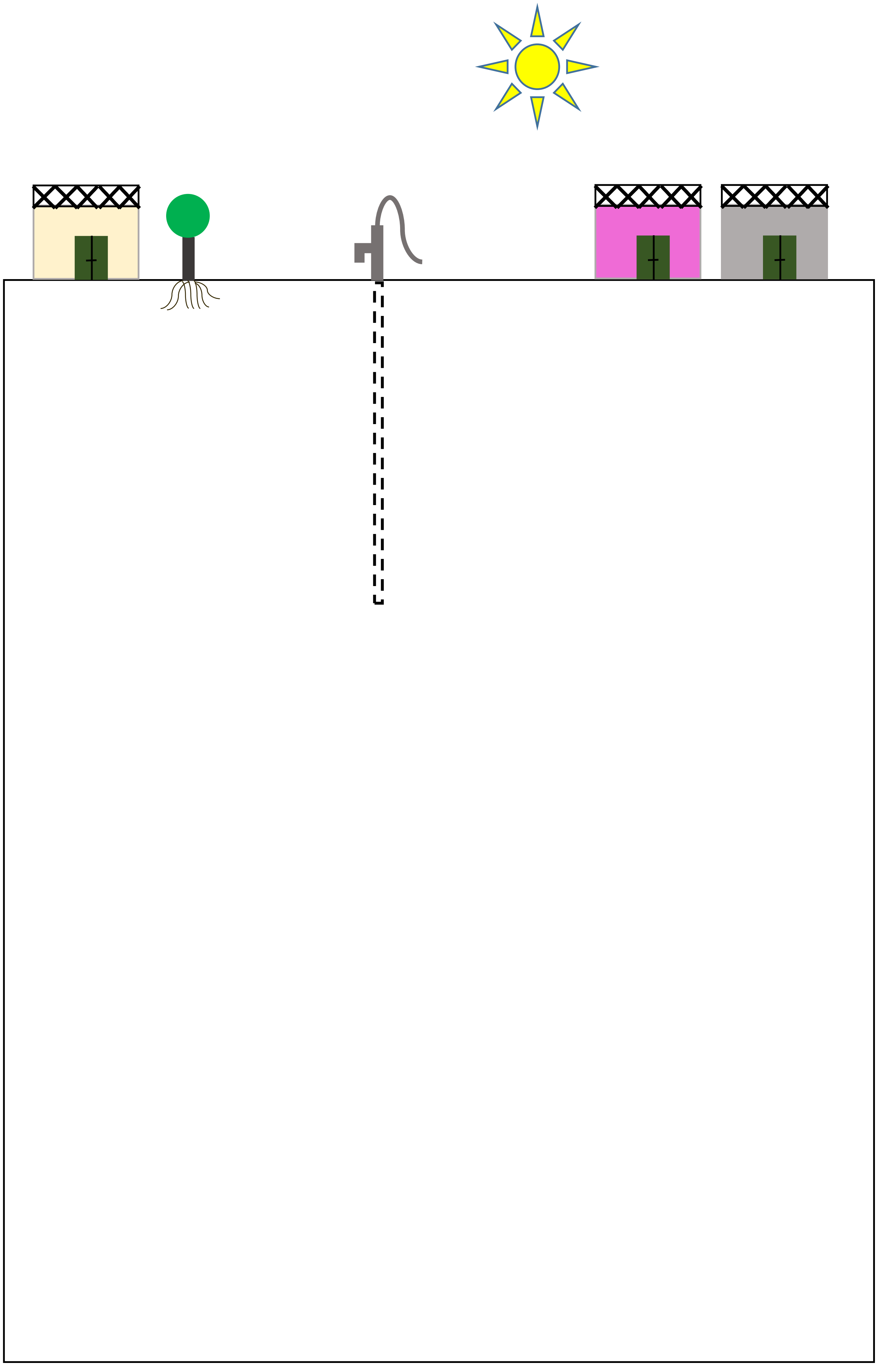
जलीय चक्र



A2 The Water Cycle – Hindi Terms

सौर ऊर्जा	सौर ऊर्जा	सौर ऊर्जा
बारिश	**बारिश**	**बारिश**
रिसना	**रिसना**	**रिसना**
भाप का निकलना	**भाप का निकलना**	**भाप का निकलना**
वाष्पीकरण	**वाष्पीकरण**	**वाष्पीकरण**
संक्षेपण	**संक्षेपण**	**संक्षेपण**
सौर ऊर्जा	सौर ऊर्जा	सौर ऊर्जा
बारिश	**बारिश**	**बारिश**
रिसना	**रिसना**	**रिसना**
भाप का निकलना	**भाप का निकलना**	**भाप का निकलना**
वाष्पीकरण	**वाष्पीकरण**	**वाष्पीकरण**
संक्षेपण	**संक्षेपण**	**संक्षेपण**

A3 Underground Drawing Sheet



A4 Water Infrastructure: Mapping Sheet – Well

Water Infrastructure: Mapping Sheet – Well

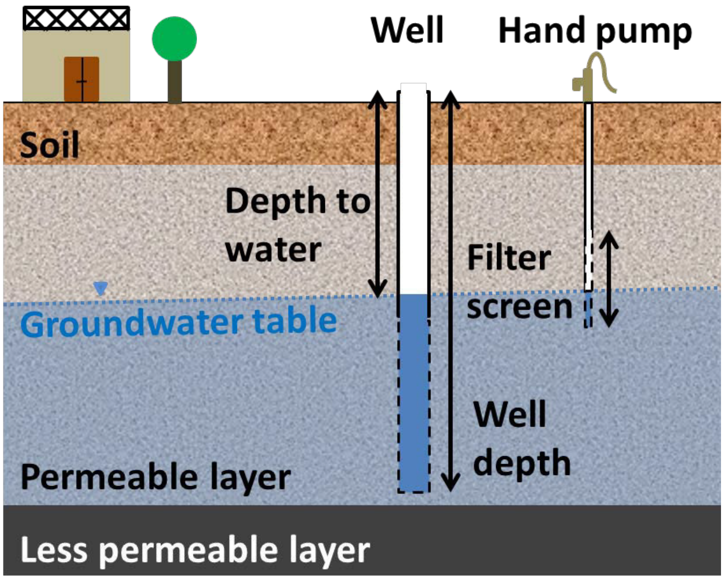
Name of scientist/assistant: ____ Date: ____________

1) General information

Community: __________________________ Well ID: _________________ Built by: ______________

GPS: ________ Number on well: _____ Landmarks: _______________________________________

2) Type



Bore well: ☐ Dug well: ☐ Step well: ☐

Hand pump: ☐ Observation well: ☐

Other: ________________________________

Well depth [ ]: _____ Diameter of well [ ]: ____

Filter screen depth [ ]: _____ - _____

3) Working

Yes: ☐ No: ☐ Reason: ____________________

____________________ Since when: ____________

4) Use

Drinking: ☐ Irrigation: ☐ Industrial: ☐ Household: ☐ Other: _______________

Private: ☐ Public: ☐ Other: ____

5) Condition

Protected: ☐ Unprotected: ☐ Partly protected: ☐

Description: ____

____

6) Possible water sampling location

Owner agreed: ☐ Many people using it: ☐ Regular water supply: ☐ Easy accessible: ☐

Groundwater available: ☐ Other: ____

7) Additional notes

____

____

____

8) Filter system (e.g. RO machine)

Yes: ☐ No: ☐

9) Photos

Number: _______________________________

A5 Water Infrastructure: Mapping Sheet – Waterline

GLOBAL RESILIENCE PARTNERSHIP

MHT Mahila Housing SEWA Trust

Freie Universität Berlin

Water Infrastructure: Mapping Sheet – Water Line

Name of scientist/assistant: ____ Date: _____________

1) General information

Community: ____ ID:___________________

GPS: ________________________Landmarks: ____

2) Connection

 Tap: ☐  Open: ☐ Bolt: ☐ Other: ________________________________

3) Use

Drinking: ☐ Irrigation: ☐ Industrial: ☐ Household: ☐ Other: _________________

Private: ☐ Public: ☐ Other: ____

4) Possible water sampling location

Owner agreed: ☐ Many people using it: ☐ Regular water supply: ☐ Easy accessible: ☐

Other:____

5) Supply times

From ______________________ To ______________________ Never: ☐

From ______________________ To ______________________

6) Additional notes

____

____

____

7) Filter system (e.g. RO machine)

Yes: ☐ No: ☐

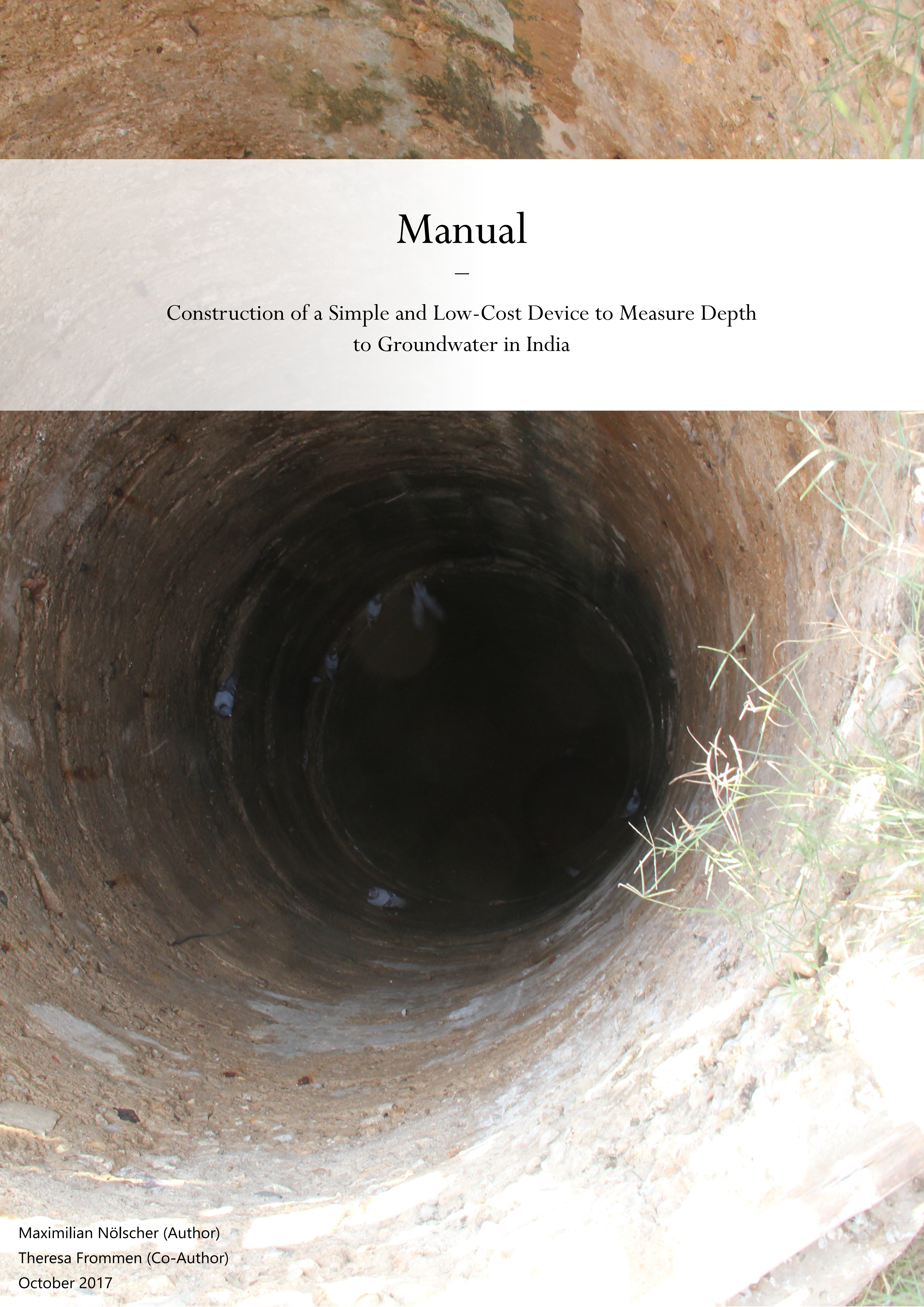
8) Number of connections

1: ☐ 2: ☐ more: ☐ How many working:______

9) Photos

Number: ____

A6 Manual: Build Your Own Water Level Meter



Manual

–

Construction of a Simple and Low-Cost Device to Measure Depth to Groundwater in India

Maximilian Nölscher (Author)
Theresa Frommen (Co-Author)
October 2017

1 What material do you need?

Tip: To prevent potential trapping
of the cable in the well,
use an extra PVC coated cable
Costs: 10 - 50 Rs per meter

2-core electric or speaker cable
length should exceed the expected
maximum depth to groundwater
Costs: ca. 10 Rs per meter

PVC insulation tape
Costs: < 50 Rs

Water tank over flow alarm
with 1 cable for power supply
and 2 cables to trigger the signal
Costs: ca. 350 Rs

Luster terminal
Costs: < 20 Rs

Extension cable
Costs: 0 Rs (if you don't have one,
ask your neighbours)

Cardboard box or a bucket
Costs: 0 Rs (common in household)

Heavy screw
or an **equivalent heavy thin weight**
Costs: 0 Rs (common in household)

2 What tools do you need?

Cable cutter

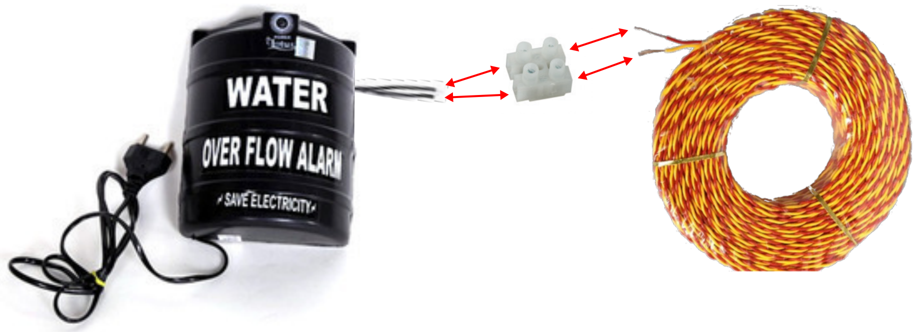
Screw driver

Waterproof pen

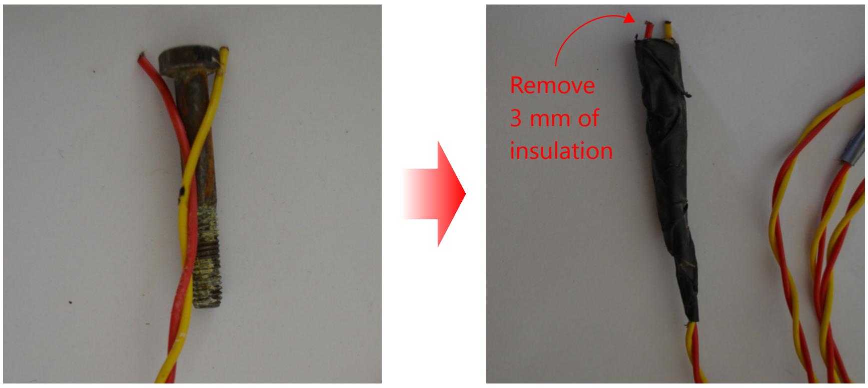
Tape measure

3 How to built the device?

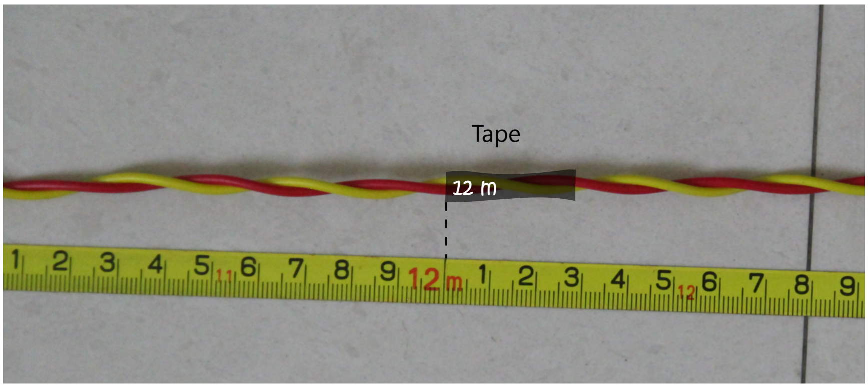
Connect the 2 lose cables of the **water tank over flow alarm device** with the 2 wires of one end of the **2-core electric or speaker cable**. Therefore use the **luster terminal**. Wrap the luster terminal with the **PVC insulation tape** to avoid the intruding of water.



At the other end of the **2-core electric or speaker cable**, put the **heavy screw** or an **equivalent heavy thin weight** between the 2 cables and wrap it with the **PVC insulation tape**. This weight is necessary to keep the wire straight while measuring. Remove just a few millimeters (ca. 3 mm) of the insulation so that the copper wire sticks out a little bit. Make sure that the 2 cabels can not touch each other.

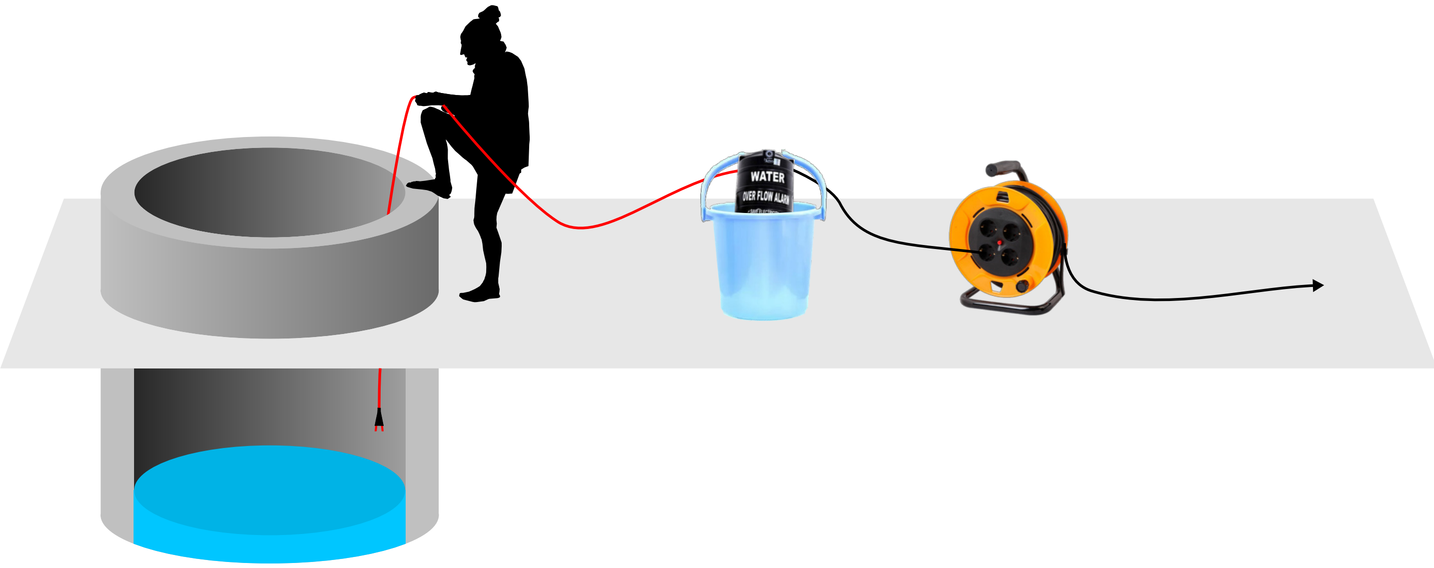


To simplify the measurement of the depth, it is recommended to mark the **2-core electric or speaker cable** in 1 m or 2 m intervals by wrapping tape around it. The zero point should be the cable end, where the screw is. Additionally, you can write the distance in m on every tape mark. Alternatively, you can also use different tape colours as marks for different intervals (lets say red tape for 10 m and black tape for 2 m intervals)

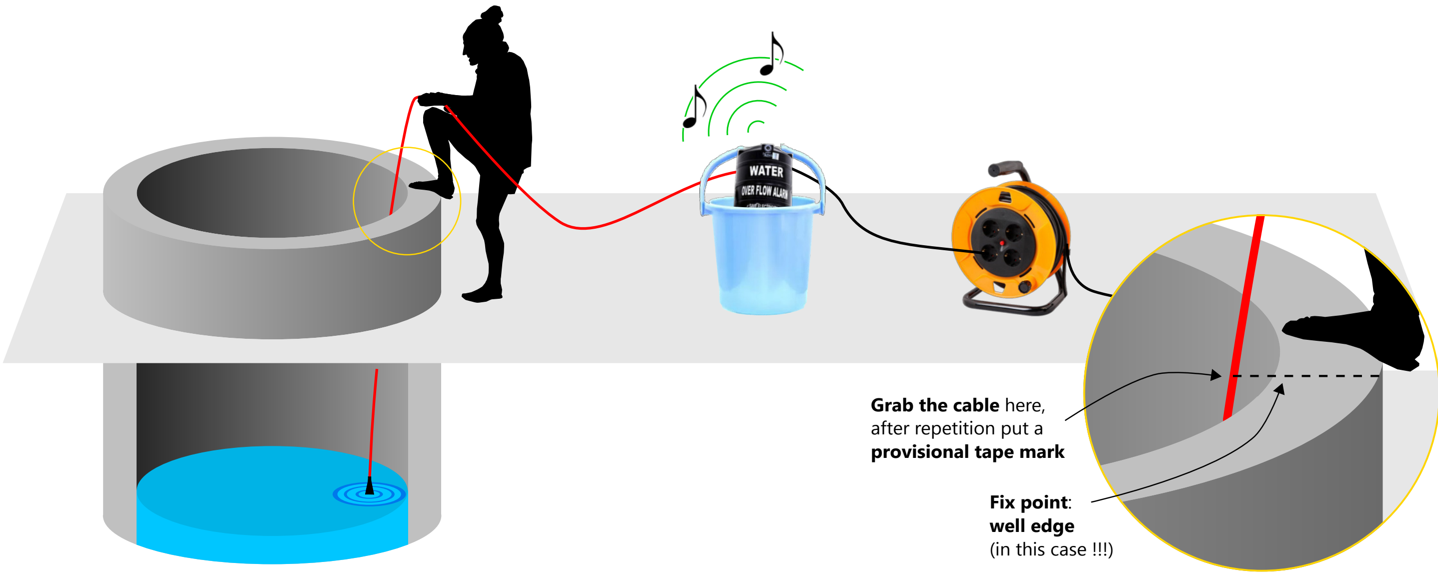


The construction of the device is basically accomplished. Now you can wrap the cable around the **cardboard box** or the **bucket** and put the other stuff like the **extension cable** and the **water tank overflow alarm** inside. Like this it can be easily transported. Many improvements are thinkable. Feel free to modify the shown construction method, which was kept consciously simple here.

4 How to measure with the device?



Set-up of the measurement device: Put the cardboard box or the bucket with the water overflow alarm and the cable together with the extension cable next to the dug well or bore well you want to measure. The extension cable can be plugged in at a near-by house. Plug in the water overflow alarm in the extension cable. Check the well for any obstacles that might interfere with the cable. Also check if the water overflow alarm is functioning by putting its end into a glass of water or by touching something made of iron. Then unwrap the cable from the box or the bucket and let it down the well.



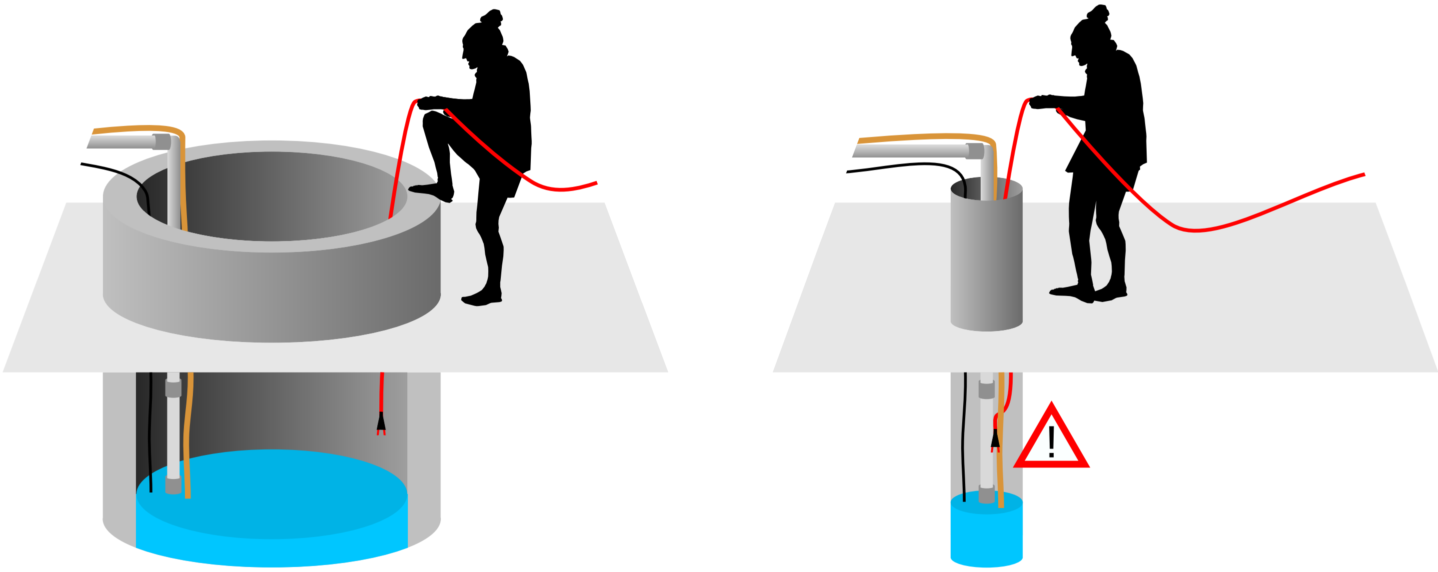
As soon as the cable end in the well touches the water surface, the water overflow alarm will make a sound. This also works if the bottom of the well is only filled with mud or wet clay. In this case you can only measure the depth of the well. When the sound of the water overflow alarm starts, you need to stop the lowering of the cable immediately. Then, **grab the cable** at the **well edge (or any other fix point** in or near the well) with one hand. Pull the cable a little bit up, untill the sound stops. Now, you should repeat the last step at least one more time. This means to lower the cable again until the sound starts. The position of your hand should be at the **well edge** (or your alternative fix point) again. If this is the case, you can assume that your measurement is correct. Now, mark the position of your hand by wrapping a **provisional tape** around the cable. Pull the whole cable up. In a last step you only need to measure the length of the cable from the cable end, which was in the well, to the position of your hand. Therefore you can use a tape measure. If you marked the cable in 1 or 2 m intervals, just measure the distance between the last mark and the **provisional tape mark** dand add the length from the cable end to the mark. Either way, as a result you now have the depth to water table value. Write down the this result together with the date, the daytime, the weather and remarkable circumstances. Dependuing on your need, repeat this measurement in daily, weekly or monthly intervals so you can evaluate the behaviour of you local groundwater table.

5 Hints and tips!

a The water overflow alarm device is often of cheap quality and therefore fragile. For a long lifetime, you should transport it carefully

b When repeating a measurement at a certain well, make sure that you always use the same fix point and remember the exact measurement methodology. It is important to repeat the measurement as identical as possible in order to be able to compare the single depth to water table values.

c During field tests it was found that during measurements in bore wells with diameters below 30 cm some troubles occured. These were caused by obstacles inside the bore well. Obstacles such as water pipes, cables for the pump, ropes and waste led the cable of our device to getting stuck while letting it down. One time it also happend that we struggled to pull the cable up again. Therefore, our tip is to primarily use dug wells for measurements as their diameter is much bigger and you can mostly follow the cable end with your eyes. If you want or need to measure inside a bore well, try to minimize potential obstacles: measure, when the pump is removed from the bore well or be sure that unnecessary objects are removed from the bore well. Another improvement could be to use an extra coated cable (as shown on page 2) instead a knurled speaker cable like we used for the prototype. Also try to keep the end of the cable as smooth as possible to prevent the cable from getting caught in the bore well.



d As already mentioned, feel free to modify and improve this measurement device. Important is a measurement as precise as possible and a comfortable handling, e.g. a simply winding and unwinding of the cable around and off the cardboard box or bucket.

A7 Water Quantity: Depth to Groundwater Measurement Sheet (coming soon)

A8 Water Quantity: Surface Water Level Measurement Sheet (coming soon)

A9 Water Quantity: Piped Water Supply Measurement Sheet (coming soon)

A10 Water Quality: Sampling Protocol

जल गुणवत्ता आंकड़ा

दिनांक: __________ समय: ________ एकत्रण कारने वाले का नाम: ____

कुंआ संख्या: _______ स्थान: ________________________________ मौसम: ___________________________

नमूना संख्या: _________________ पंमपिग शुरु:_______ पंमपिग समाप्त : _______ पंमपिग का समय : _______

परिवेश:

कचरा: ☐ घरेलू व्यर्थ: ☐ पशु: ☐ कृषि: ☐ औद्योगिक व्यर्थ: ☐ धोना: ☐ मल: ☐

रंग: 

____

गंध:

नहीं	क्लोरीन	गंधक (सड़े हुए अंडे)	मिट्टी की/ मछली का	पेट्रोल	तेज रासायनिक	अन्य

	P.	पाचल [मिलीग्राम / एल]	निरीक्षण मूल्य	मानक (IS 10500 : 2012)		टिप्पणियों
				स्वीकार्य सीमा	अनुमेय सीमा	
1.		हवा का तापमान [डिग्री सी]		-		
	20	तापमान [डिग्री सी]		-		
2.	18	पी. एच. (इकाइयों)		6.5 - 8.5		
3.	33	फ्लोराइड		1	1.5	
4.	27	धुंधलापन [एन. टी. यू.]		1	5	
5.	42	अमोनिया		0.5		
6.	31	नाइट्रेट		45		
7.	37	लोह तत्व		0.3		
8.	40	कठोरता		200	600	
9.	29	क्लोराइड		250	1000	
10.	-	टी.डी.एस [मिलीग्राम/एल]		500	2000	
	-	विद्युत चालकता [µS/cm]				टी.डी.एस ≈ विद्युत चालकता x 0.65
11.	44	मल प्रदूषण		अनुपस्थित		
12.	22	घुली ऑक्सीजन		-		

टिप्पणियों:

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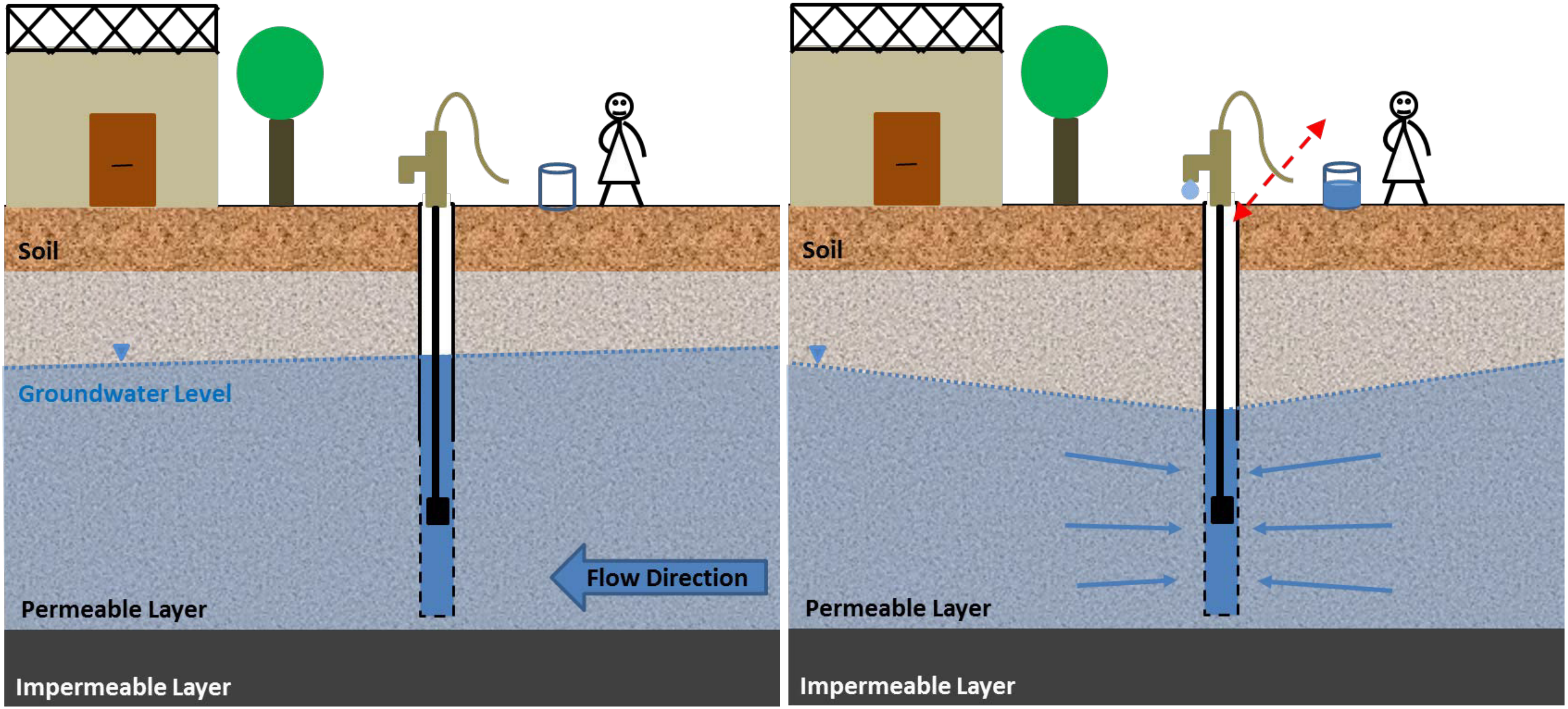
अंत समय: _________________________

A11 Why to Pump Before Taking a Sample

Freie Universität Berlin

Why to pump before taking a groundwater sample



A12 Water Quality: Record Sheet

GLOBAL RESILIENCE PARTNERSHIP
CONVENED BY THE ROCKEFELLER FOUNDATION AND USAID

Mahila Housing SEWA Trust

Freie Universität Berlin

Water Quality Record Sheets

Monthly variations in key water quality parameters

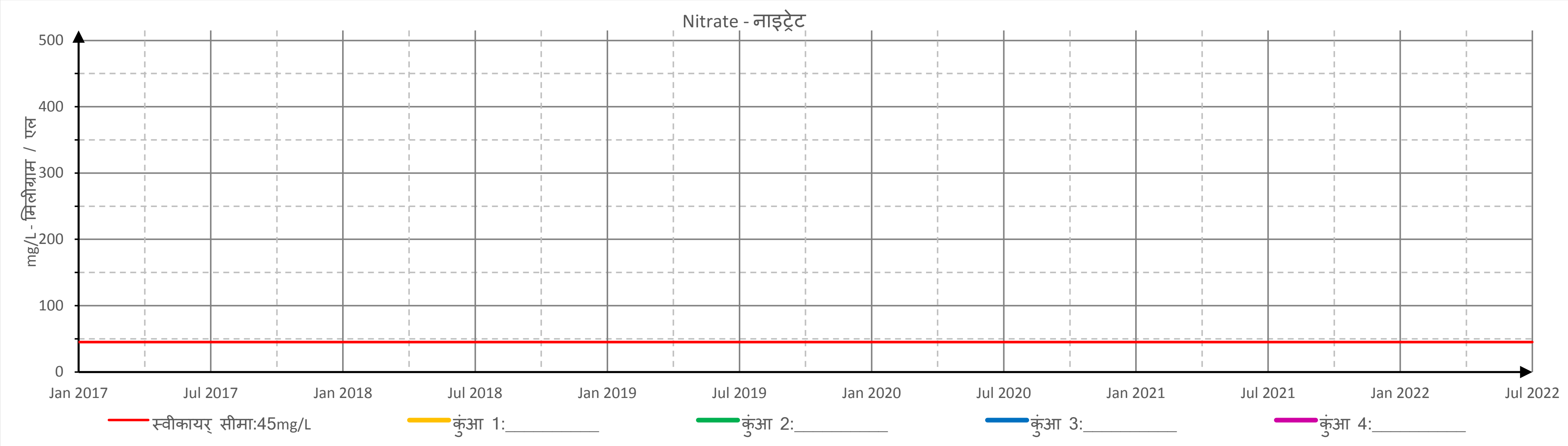
January 20__ — January 20__

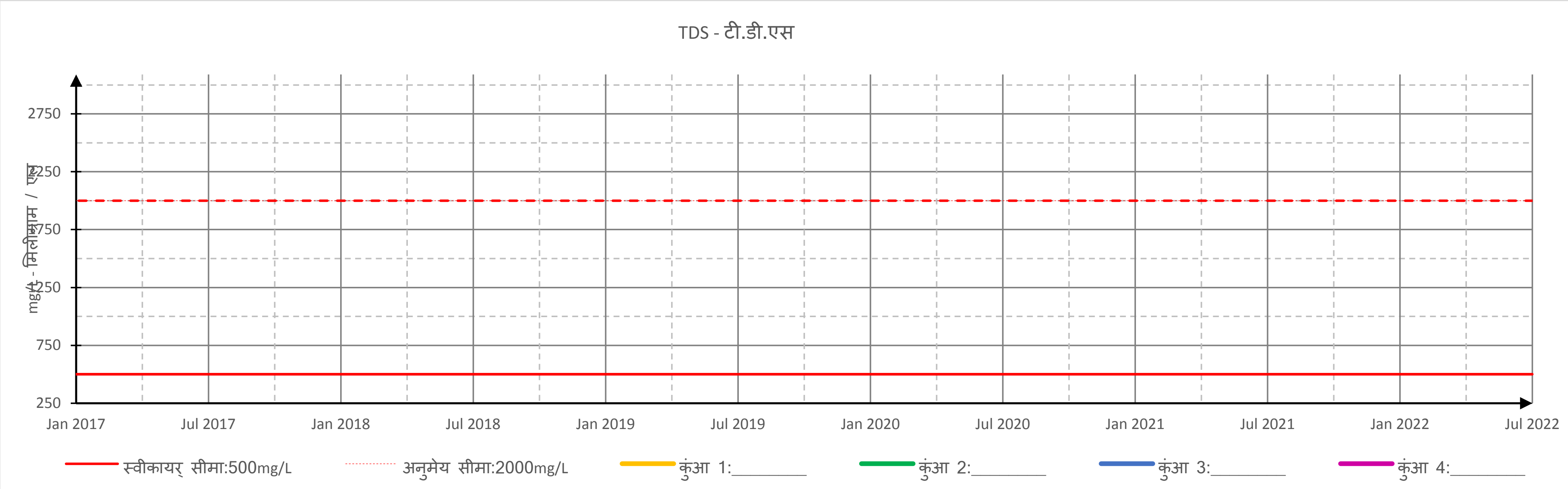
स्थान: ____

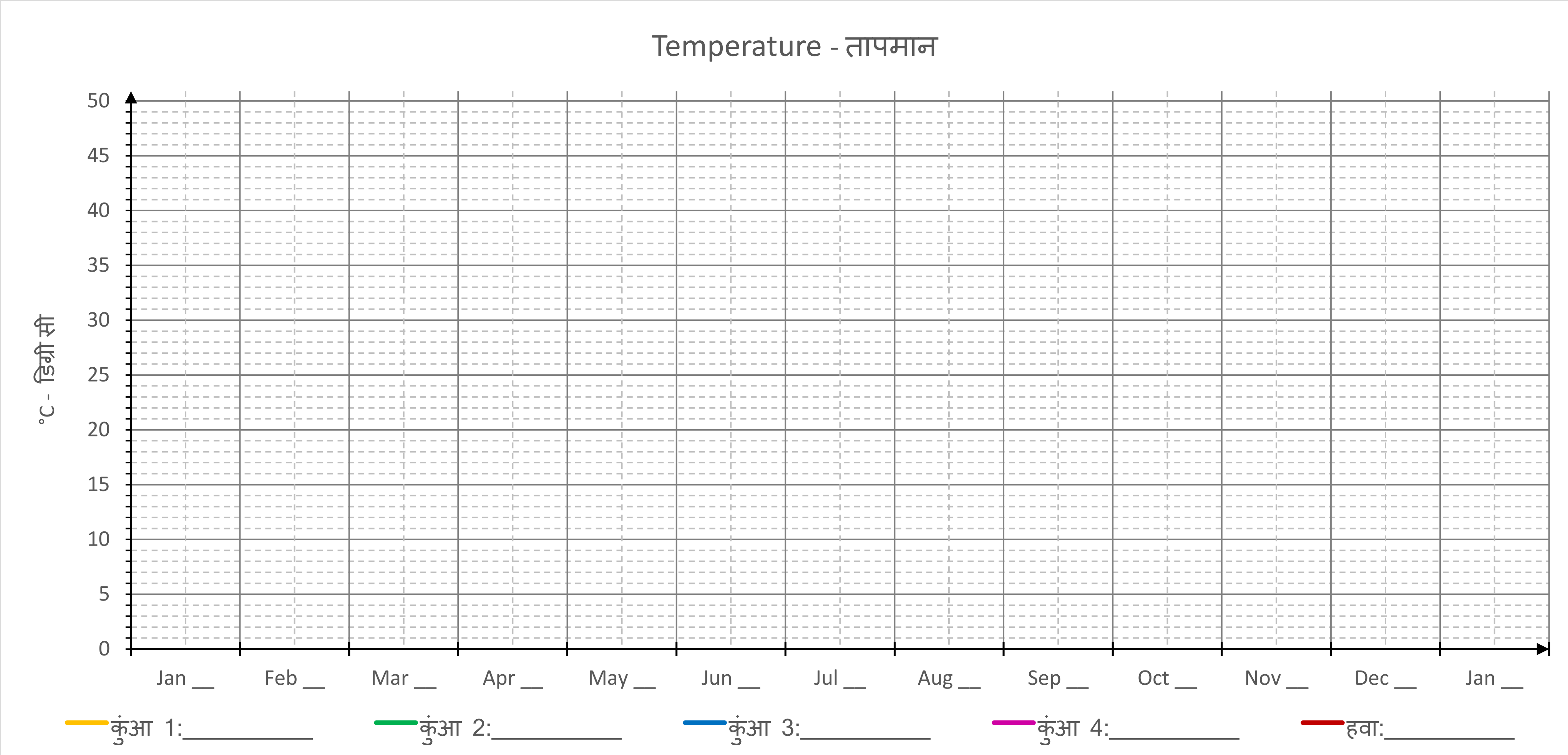
एकत्रण कारने वाले का नाम: ____

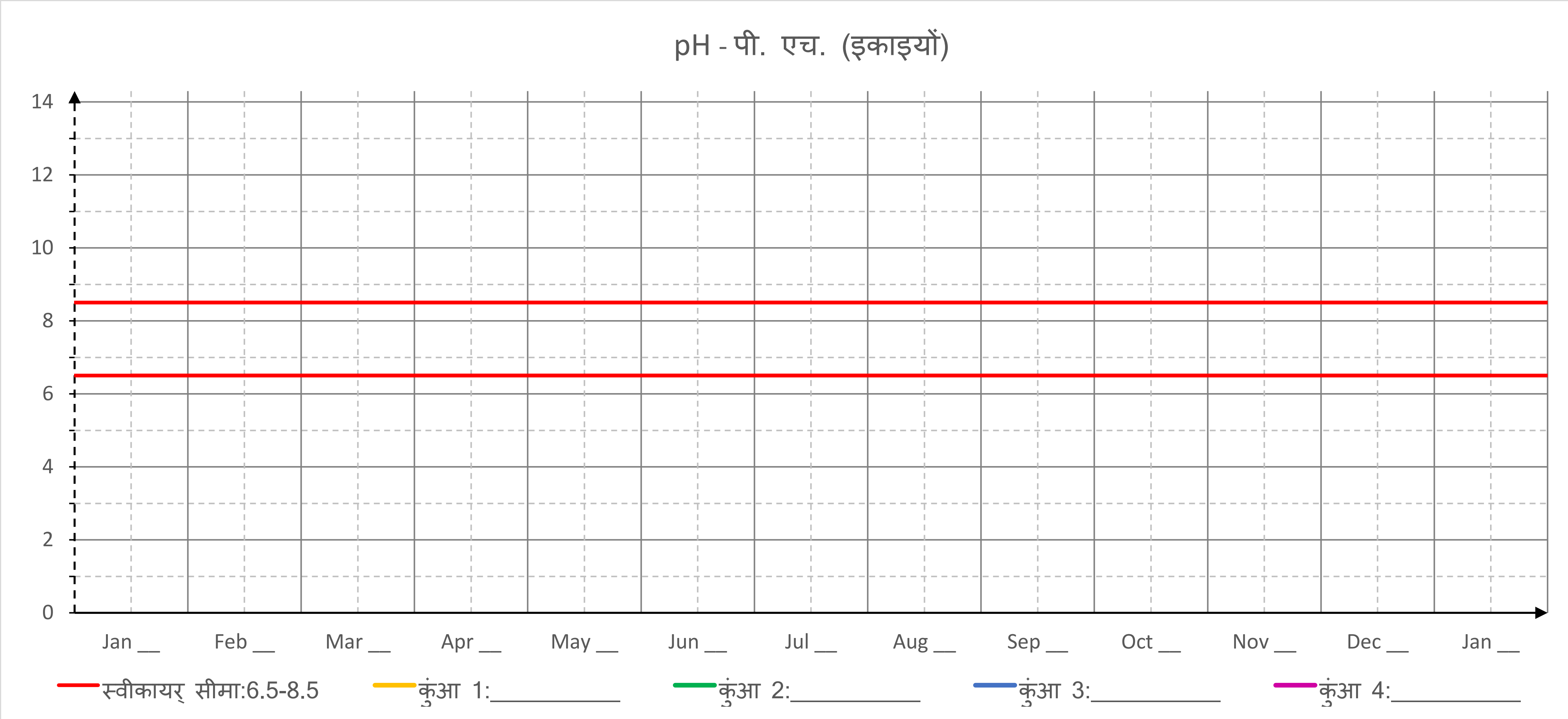
उपकरण: ____

Examples - उदाहरण



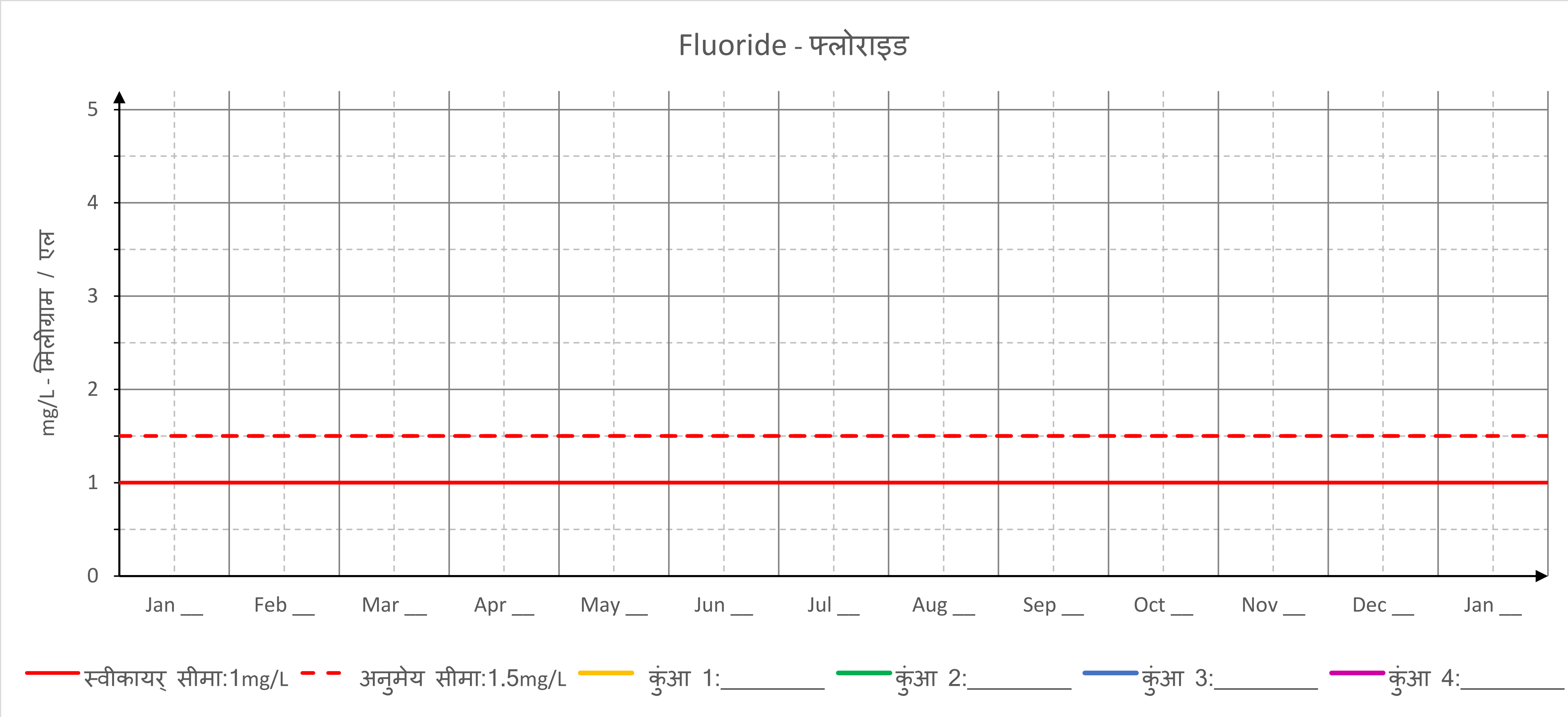



Temperature - तापमान
°C - डिग्री सी
50
45
40
35
30
25
20
15
10
5
0
Jan __
Feb __
Mar __
Apr __
May __
Jun __
Jul __
Aug __
Sep __
Oct __
Nov __
Dec __
Jan __
कुंआ 1:___________
कुंआ 2:___________
कुंआ 3:___________
कुंआ 4:___________
हवा:___________



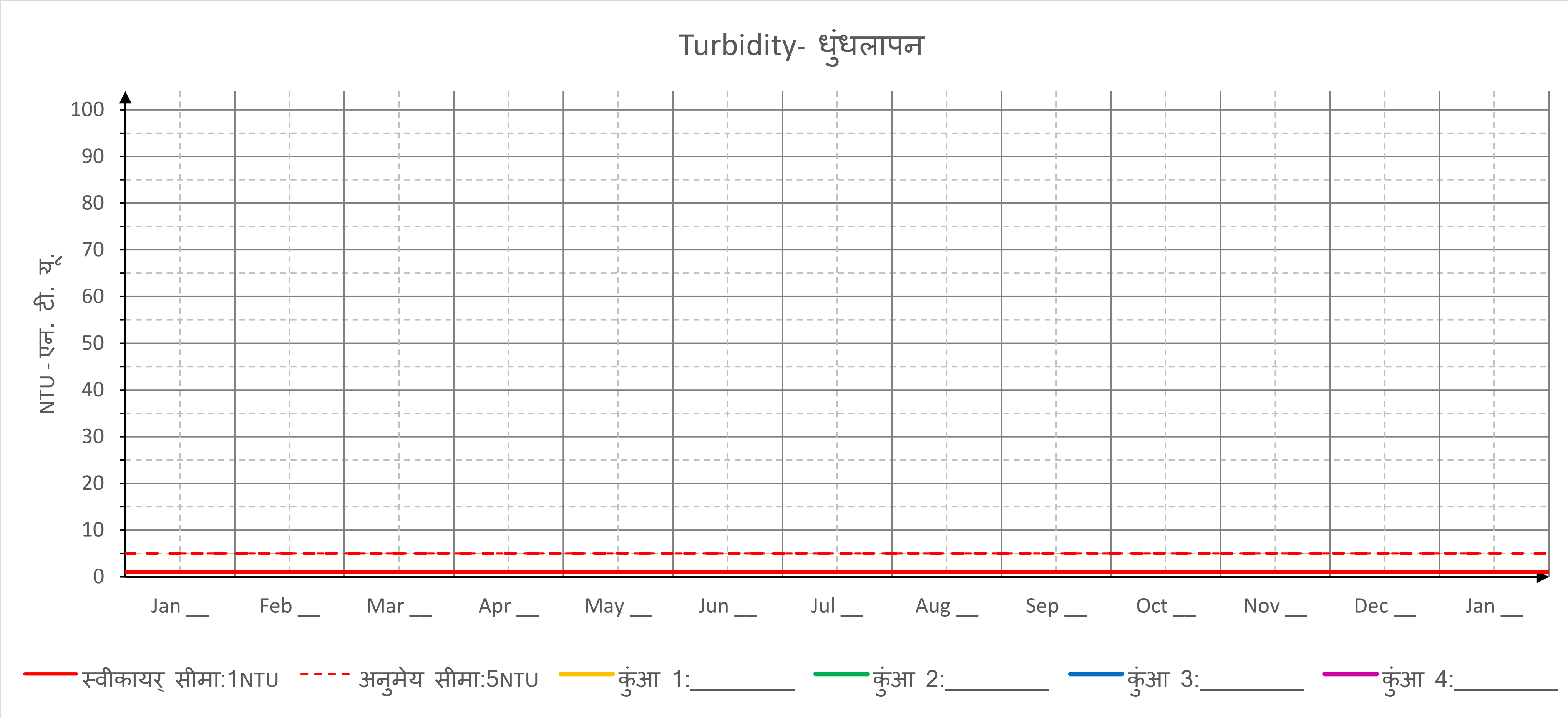
Health Concerns: Negligible; (But: high pH causes a bitter taste, water pipes etc. become encrusted; low pH will corrode or dissolve metals and other substances)

Sources: Natural and human influences



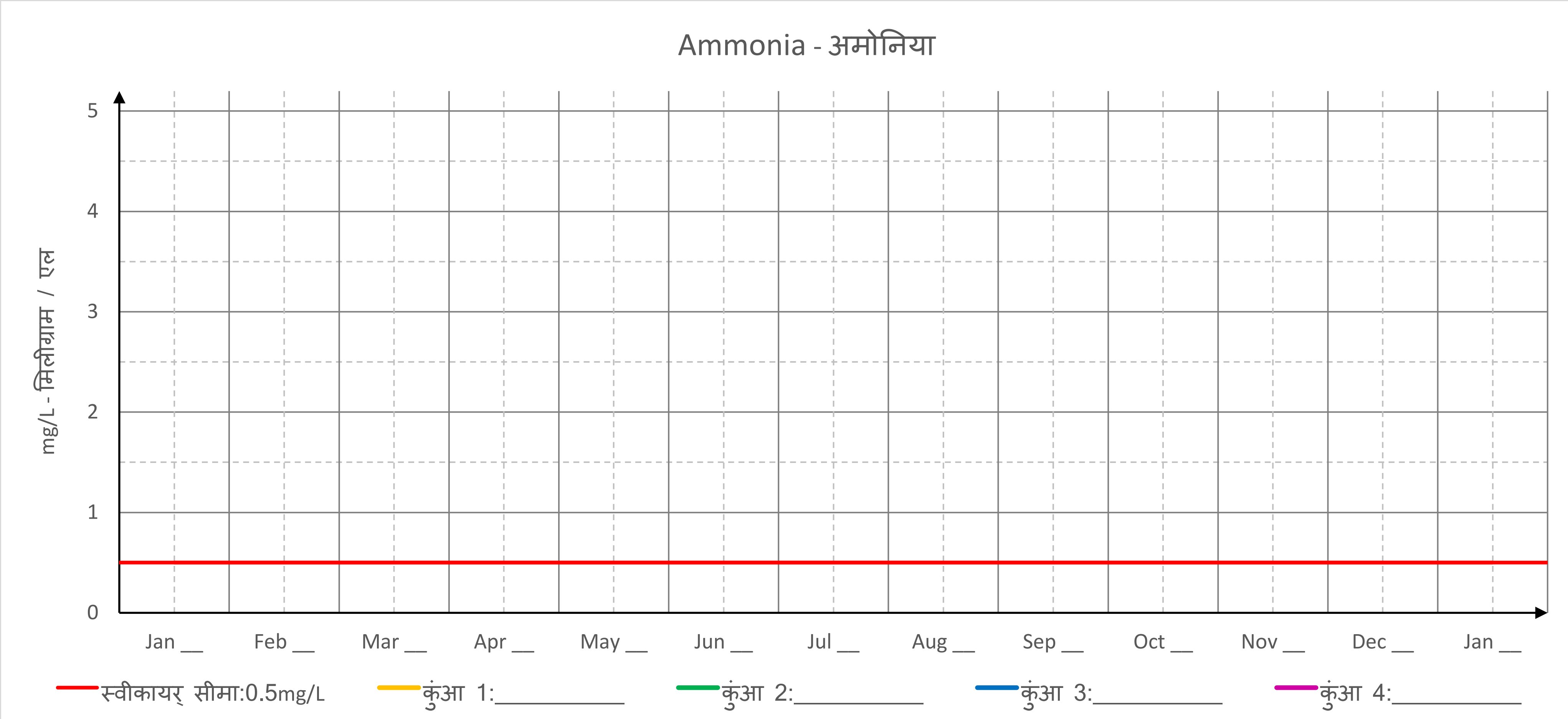
Health Concerns: Dental fluorosis (tooth mottling); skeletal fluorosis (bone deformation and painful brittle joints in older people)

Sources: Salts and sedimentary F-bearing minerals are the primary sources; dying and printing industries effluents



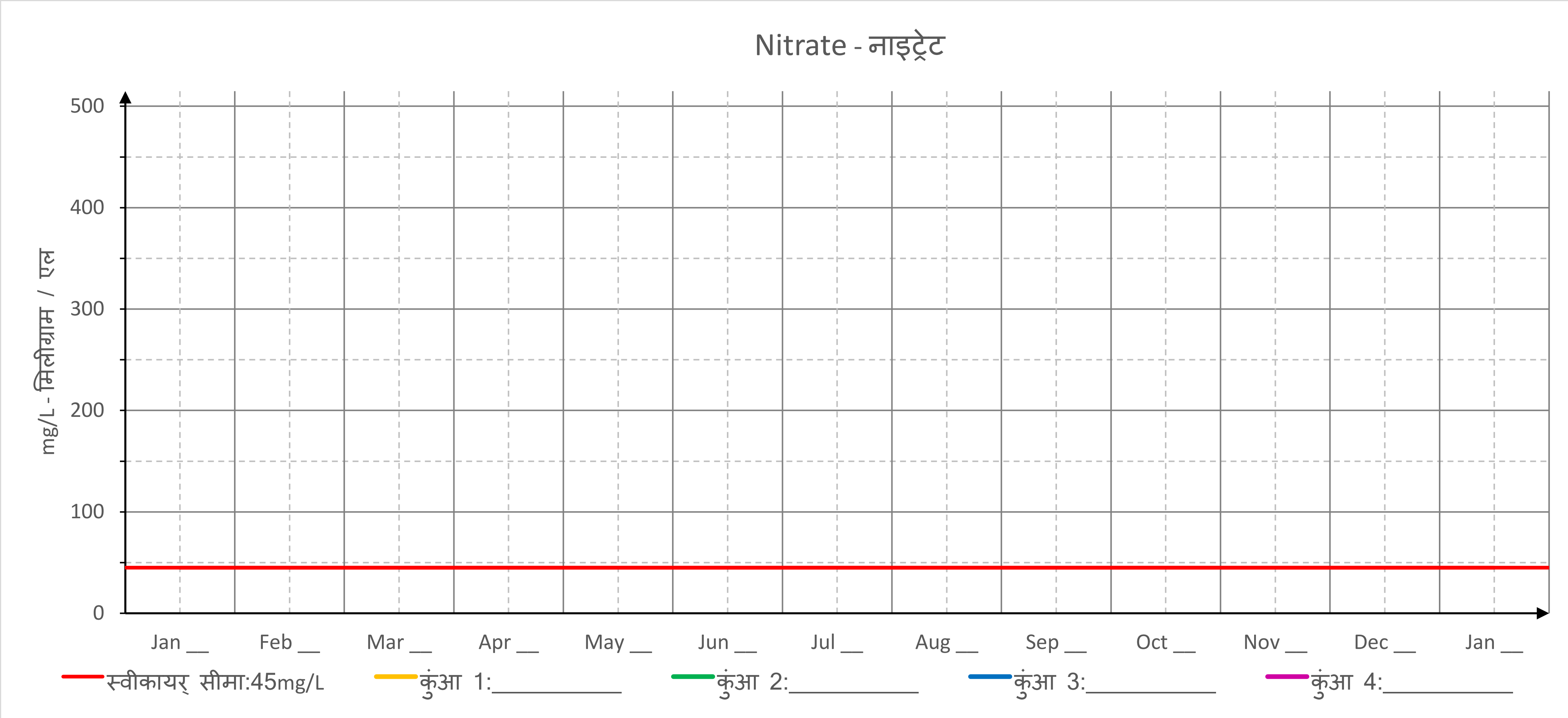
Health Concerns: Not directly, but turbidity can provide food and shelter for pathogens → water-borne diseases

Sources: Clay, silt, finely divided inorganic and organic matter, algae, soluble colored organic compounds and other microscopic organisms



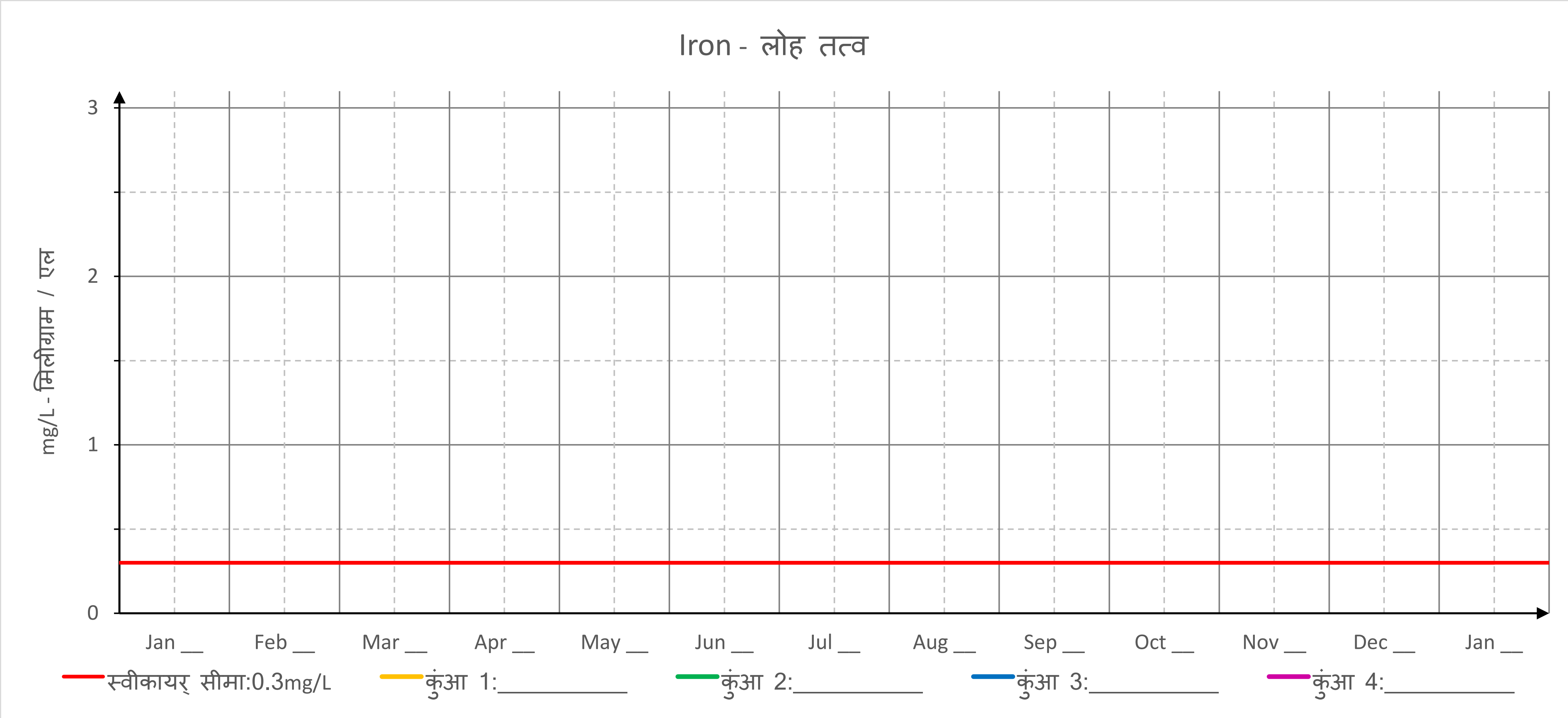
Health Concerns: None for humans at low concentrations (toxic for aquatic species)

Sources: Sewage discharge; industrial discharge; fertilizers



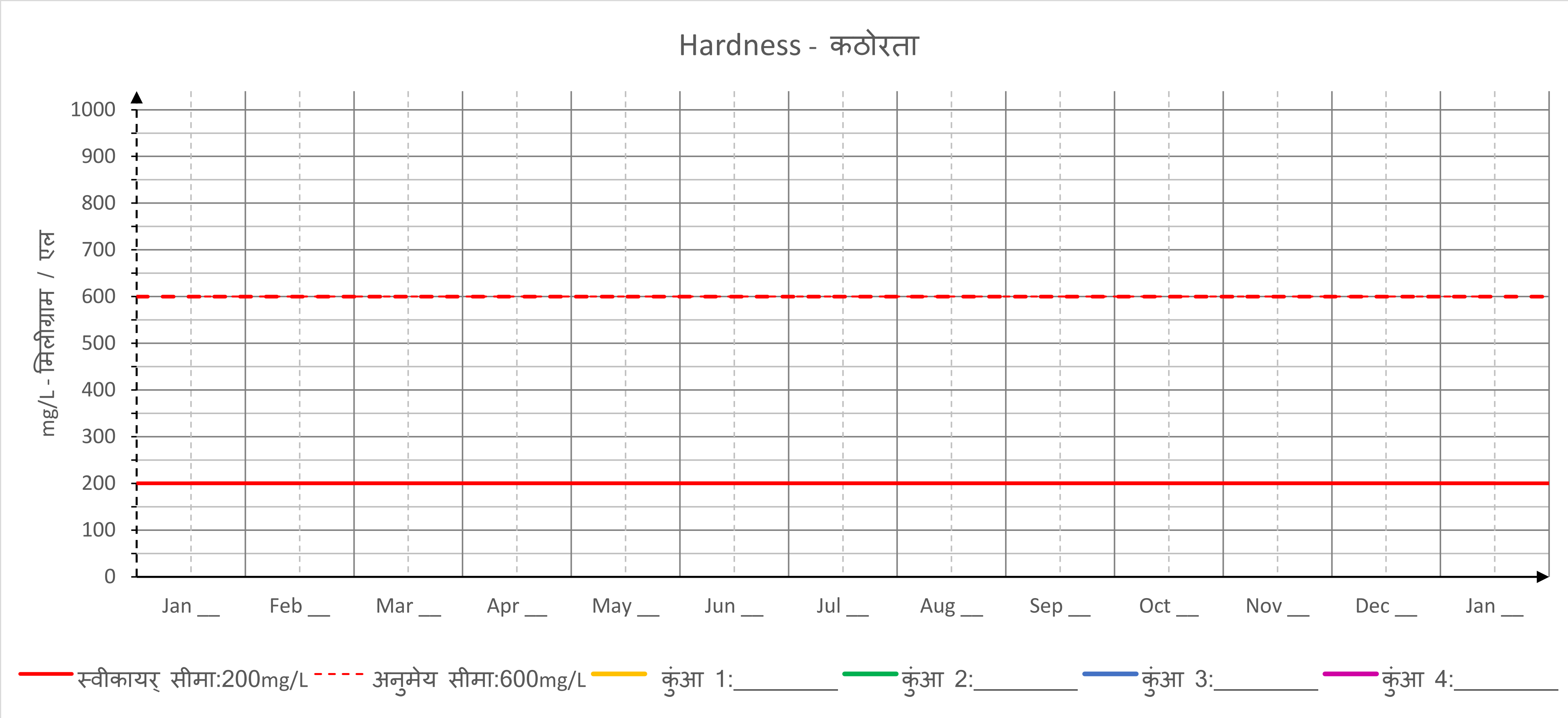
<u>Health Concerns:</u> Excessive nitrate intake can result in diarrhoea or methaemoglobinaemia (blue-baby syndrome) in infants

<u>Sources:</u> Chemical fertilizers; animal matter; domestic effluents; sewage sludge disposal; industrial discharge



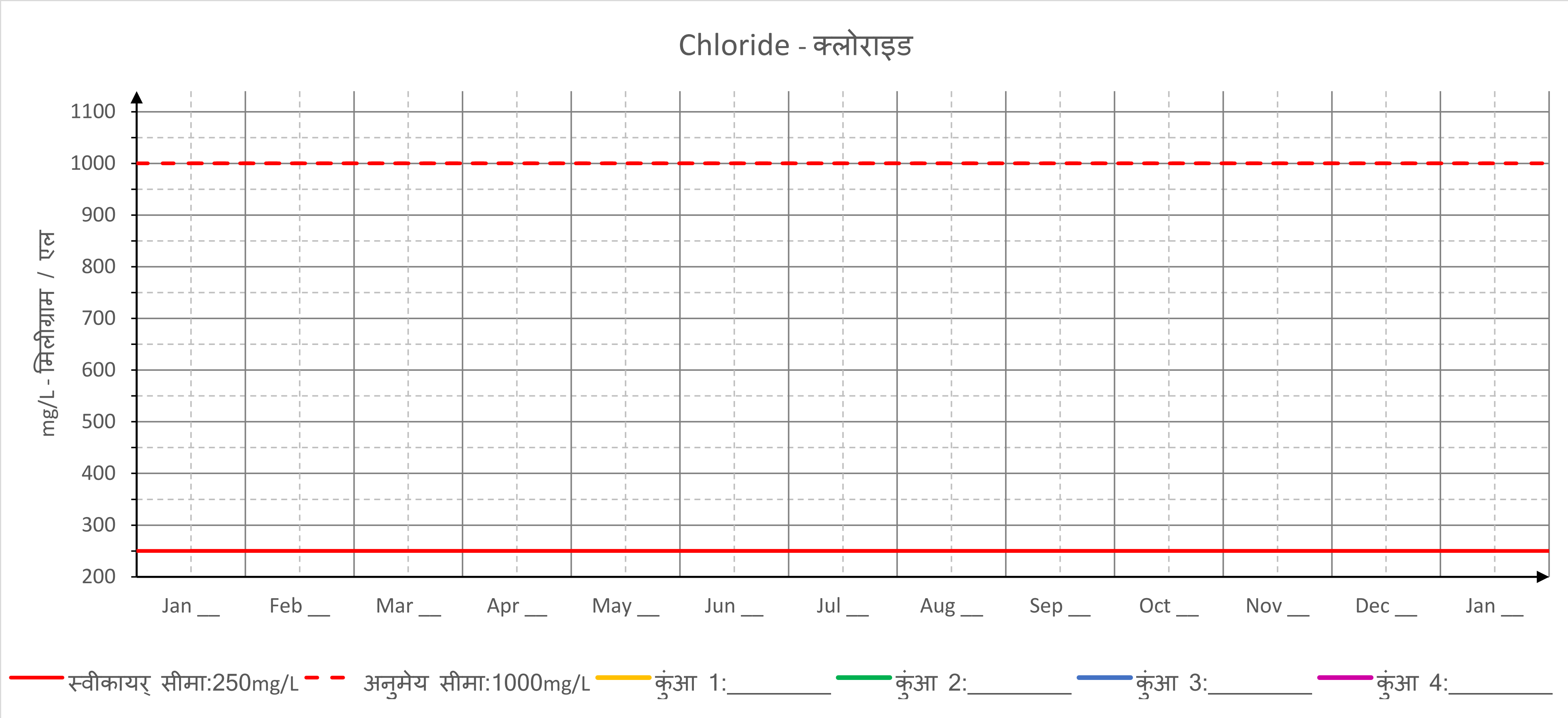
Health Concerns: Negligible; limits based on aesthetics rather than physiological effects

Sources: Natural (geogenic) sources



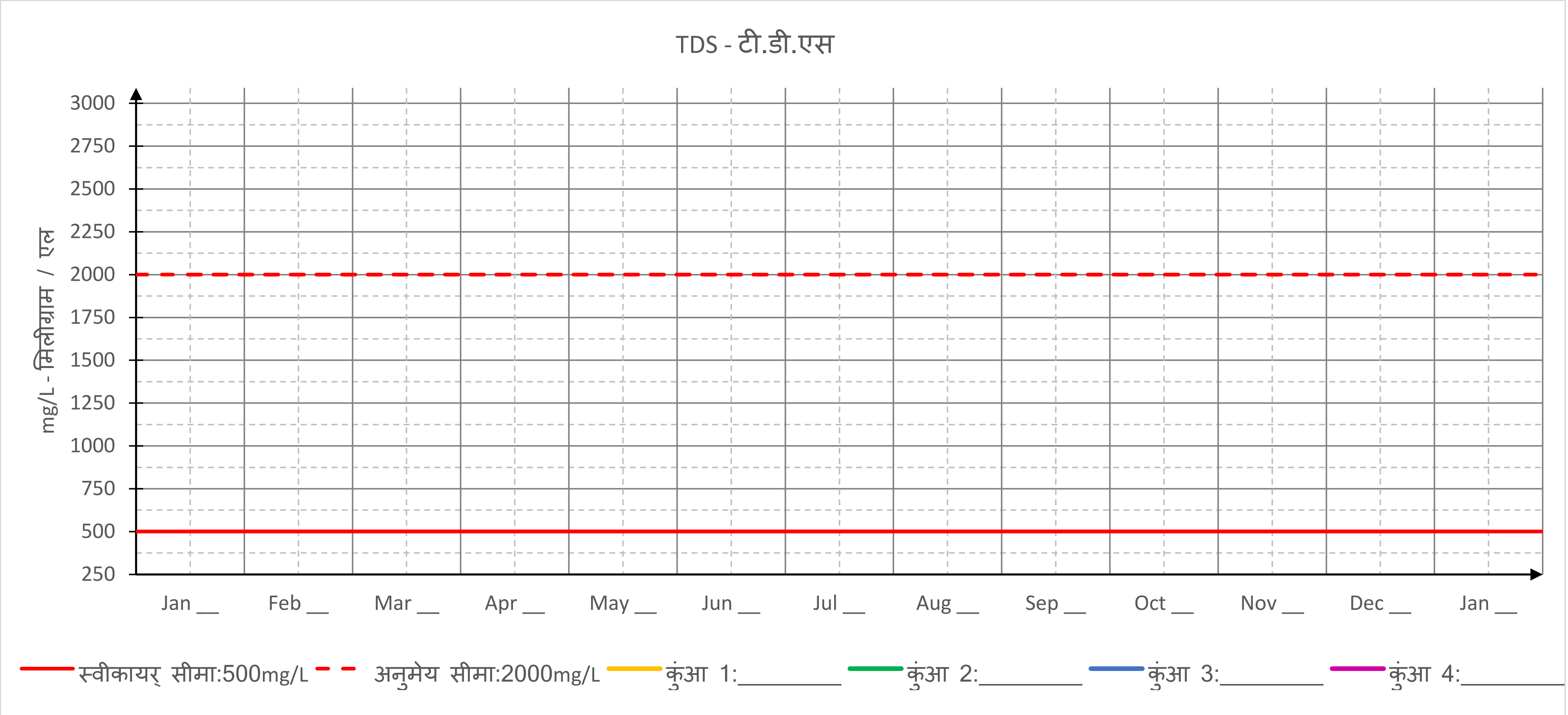
Health Concerns: Negligible; (But: can cause mineral buildup in plumbing, fixtures, and water heaters, and poor performance of soaps and detergents)

Sources: Natural (geogenic) sources, e.g. carbonatic rocks; industrial discharge; discharge from mines



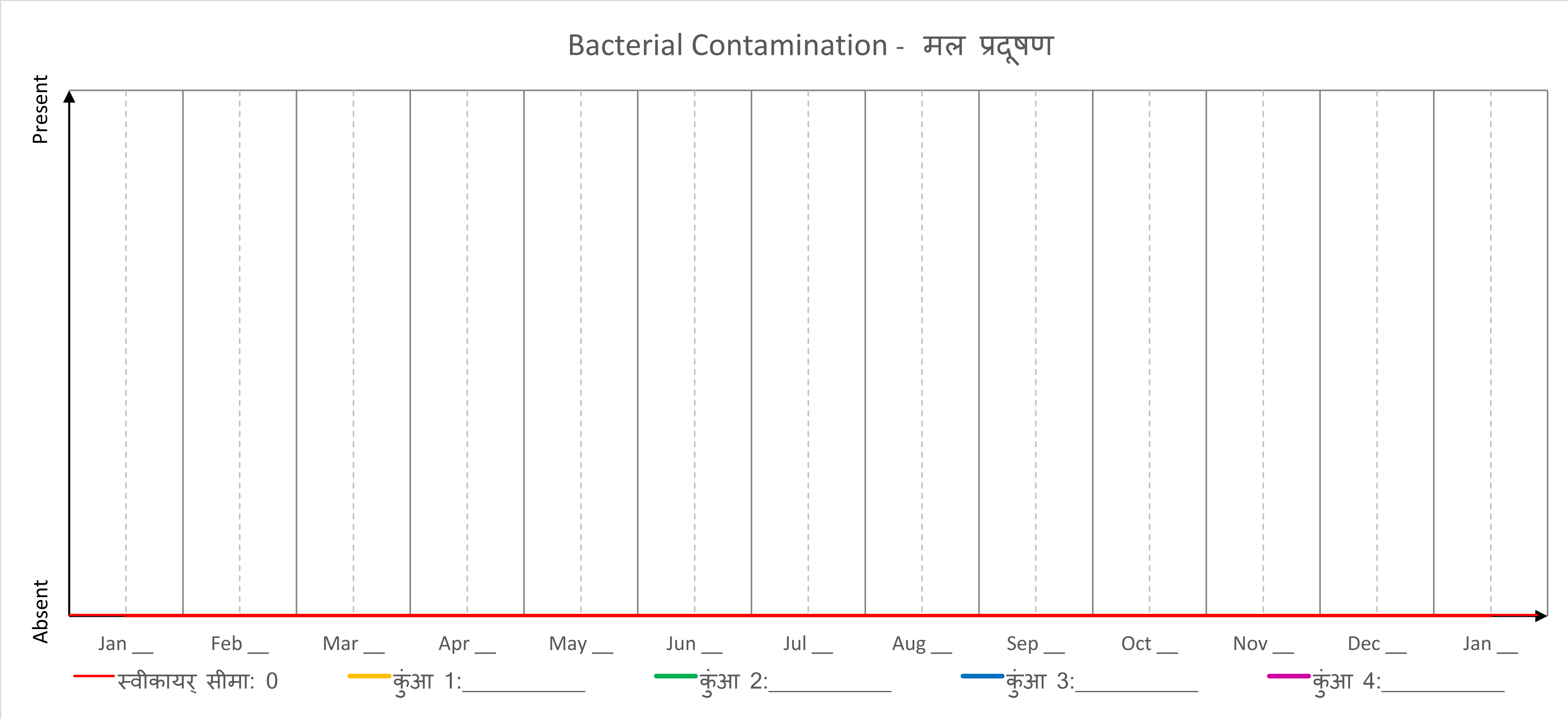
<u>Health Concerns:</u> Negligible; (But: increases corrosivity)

<u>Sources:</u> Chemical industry discharge; sewage discharge; irrigation drainage; natural sources



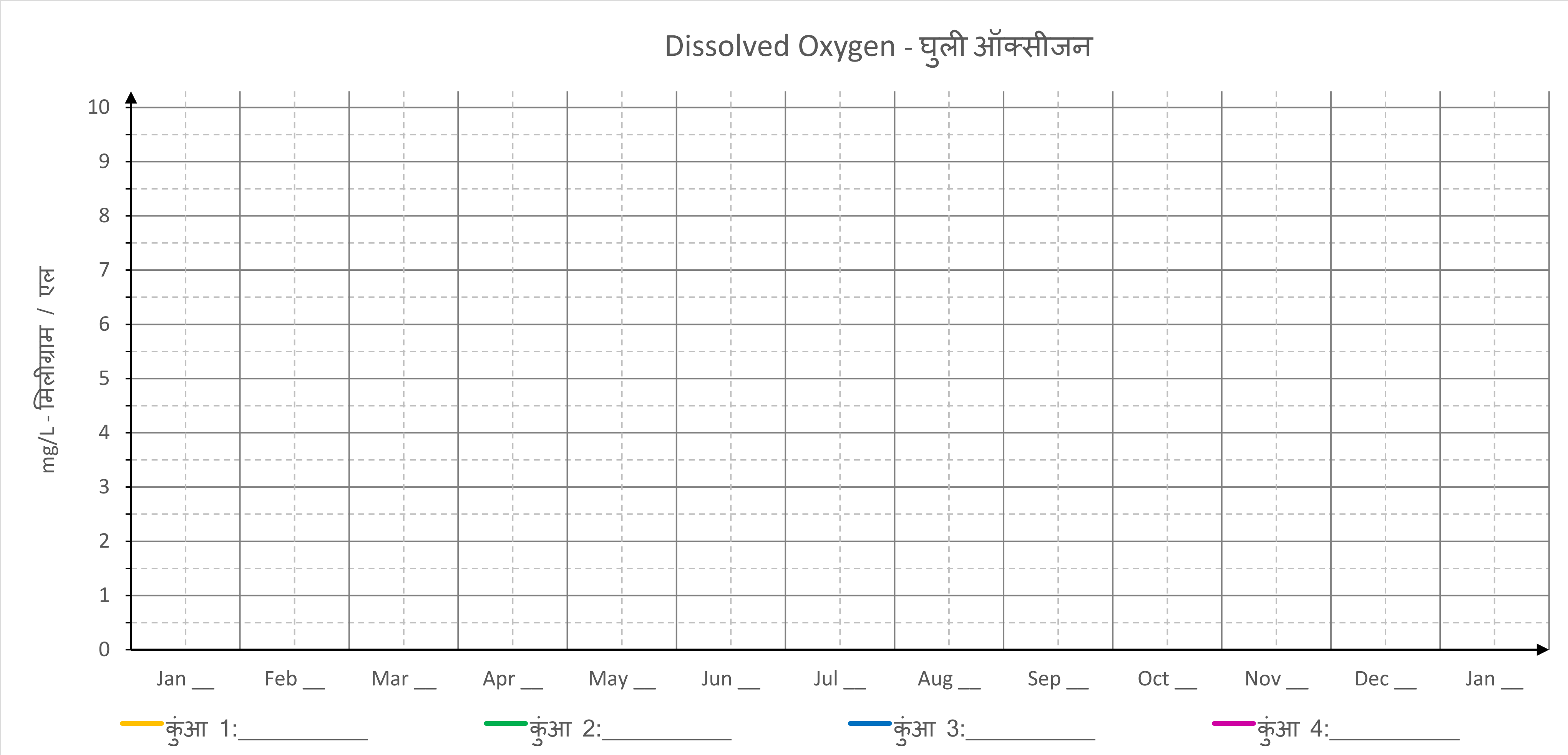
<u>Health Concerns:</u> Negligible; (But: taste decreases and excessive scaling in water pipes etc. takes place)

<u>Sources:</u> Natural sources; sewage; urban and agricultural run-off; industrial wastewater



<u>Health Concerns:</u> Typhoid, dysentery, diarrhea (and other water-borne diseases)

<u>Sources:</u> Human and animal wastes



Health Concerns: Negligible;

Sources: Mixing of water with atmosphere