Urban Rainwater Harvesting in Hyderabad

An option to overcome the water crisis of a megacity of tomorrow?

Masterthesis

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Abstract

Water is one of the most important resources on this planet. Human water consumption has quadrupled worldwide during the last 50 years. Almost half a billion people live in countries where water is scarce. Cities and especially cities in developing countries are more and more confronted with problems of water scarcities. This paper will take a look at the potential of rain water harvesting for the domestic water supply of the South Indian city of Hyderabad. Calculations based on semi-structured interviews of households in slum and middle class areas show that an average household in a slum area could supply itself with a daily amount of 75 l of water for 177 days of the year using a simple rainwater harvesting system. It would be especially during Monsoon, that this would significantly improve the situation of slum dwellers, since they are often subject to illnesses caused by soiled or contaminated tap water. The cost-benefit analysis juxtaposes its investment costs of a rainwater management system with the potential savings and the potential private and communal benefits. This highlights some problems concerning the realization of urban rainwater harvesting projects. Many households in slum areas for example lack the willingness to invest in such a project because of an unclear ownership status on the one hand and lacking financial incentives and a lack of knowhow of rainwater harvesting and its potential benefits on the other. This study gives an overview of the current physical and socio-economic boundary conditions, the potential problems and benefits of urban rainwater harvesting in Hyderabad. It wants to give a basis for decision makers involved in related projects to consider rainwater harvesting as a potential supplement to Hyderabad's domestic water supply.

Keywords: Urban Rainwater Harvesting, Megacity, Domestic Water supply, Micro Water Balance

Kurzfassung

Wasser ist eine der wichtigsten Ressourcen der Erde. Der Wasserverbrauch durch den Menschen hat sich in den letzten 50 Jahren weltweit vervierfacht. Nahezu eine halbe Milliarde Menschen leben in Ländern, in denen bereits Wasserknappheit herrscht. Städte und insbesondere Städte der Entwicklungs- und Transformationsländer sind in zunehmendem Maße von den Problemen der Wasserknappheit betroffen. Diese Arbeit gibt Aufschluss darüber, inwiefern urbane Regenwasserbewirtschaftung zur Verbesserung der Haushaltswasserversorgung der südindischen Metropole Hyderabad beitragen kann. Basierend auf semistrukturierten Interviews von Slum- und Mittelklassehaushalten ergaben die Berechnungen eines Microwasserbilanzmodells, dass ein durchschnittlicher Slum Haushalt sich 177 Tage im Jahr mit 75l Wasser pro Tag mit einer einfachen Regenwasserbewirtschaftungsanlage versorgen könnte. Besonders während der Monsunzeit, in der es vermehrt zu wasserbürtigen Krankheiten aufgrund von verschmutzem Leitungswasser kommt, könnte dies eine essentielle Verbesserung vor allem für Menschen in Slums darstellen. In einer Kosten- Nutzenanalyse werden die Kosten einer solchen Anlage den potentiellen Ersparnissen und den privaten sowie allgemeinen Nutzen gegenübergestellt. Hieraus ergeben sich einige Probleme hinsichtlich der Realisierung urbaner Regenwasserbewirtschaftung. Neben mangelnder Investitionssicherheit, verursacht durch die unklareren Eigentumsverhältnisse in Slumgebieten, fehlt es in den meisten Haushalten an Investitionsbereitschaft aufgrund fehlender finanziellen Anreize bzw. fehlenden Wissens über Regenwasserbewirtschaftung und dessen Potentials. Diese Studie vermittelt einen Überblick über die derzeitigen physischen und sozioökonomischen Rahmenbedingungen, Hemmnisse und Potentiale urbaner Regenwasserbewirtschaftung in Hyderabad. Sie soll dazu beitragen, eine Grundlage für Entscheidungsträger zu schaffen, urbane Regenwasserbewirtschaftung als eine mögliche Ergänzung zur Haushaltswasserversorgung einordnen zu können.

Stichwörter: Urbane Regenwasserbewirtschaftung, Mikrowasserbilanzierung, Megacity, Haushaltswasserversorgung

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Nomenclature

AMSL . . . . Above Mean Sea Level

AP . . . . Andhra Pradesh

APPCB . . . . Andhra Pradesh Pollution Control Board

APWALTA . . . . .Andhra Pradesh Water Land and Trees Act, 2002

APSMFC. . . . . . Andhra Pradesh State Minorities Finance Corporation

BHUMI . . . . .Local NGO for Rasoolpura originally a subgroup of BHarat Uday BIS

BMBF . . . . .Bundesministerium für Bildung und Forschung

CGWB . . . . Central Groundwater Board

DEM . . . . .Digital Elevation Model

GHEP . . . . .Green Hyderabad Environment Program

HMWSSB . . . . . Hyderabad Metropolitan Water Supply and Sewage Board

HUDA . . . . Hyderabad Urban Development Authority

LPCD . . . . Liter Per Capita Per Day

MCH . . . . Municipal Corporation of Hyderabad

MGD . . . . .Million Gallons Daily

INR. . . . . Indian Rupees

RWH. . . . . .Rainwater Harvesting

Introduction and Purpose of the Study

As a Megacity of tomorrow Hyderabad has a current population of just above six million which is expected to more than double by 2021 to approximately 13.6 million (MCH 2006). With continuing high growth rates, the provision of adequate amounts of safe water becomes an increasingly complex and expensive task. The supply intervals of drinking water have declined over the years, from 19 hours per day in the early 1980ies to 1.5 hours per day in the 2000s (Reckien et al 2009). Shortages in water supply, the drying up of reservoirs and steadily declining groundwater show that Hyderabad’s urban water household is out of balance. A city has basically three options to react to permanent water shortages: use of new sources, more efficient water use and recycling of water. Hyderabad focuses very much on the first option and invested a lot of money to increase its water supply capacity by extending existing long distance supply from reservoirs and building new dams in the Krishna basin (MCH 2006). But still the water availability is not sufficient in many parts of the city. The Reservoirs are located far out of the city and a lot of water is lost on the way into the city due to leakages and illegal connections (Ramachandraiah 2007). But also in the city the distribution infrastructure is in many parts antiquated and some parts of the city still have no tap connection.

Another challenge the City is facing every year is to cope with the water masses delivered by the monsoon. During the monsoon season strong precipitation events regularly lead to the inundation of houses and roads especially in the low lying areas of the city. These two extremes, having a lack of water availability during periods of dryness on the one hand and urban floods during the monsoon on the other will be amplified by climate change with high probability. A Study of Luedeke et al 2009 had shown that “Hyderabad has to prepare for about a doubling of extreme precipitation events (daily rainfall) until 2050 and a potential, but still uncertain change in total annual precipitation. The total annual precipitation will be distributed more unevenly, so that both longer dry periods and an increase in the amount of rainfall are possible.” So the situation, that in one part of the year the city is suffering from water scarcities and in the other part of the year gets flooded, could even be intensified in the future. To find a solution for this paradox situation other strategies besides the centralist approach of building new dams have to be identified and tested. One possible strategy could be capturing and using the rainwater exactly where it falls: rainwater harvesting. The technique of rainwater harvesting is an old technique and is widely used all over India, but mainly in the rural areas. Actually building dams is also a centralized form of rainwater harvesting on a large scale. The Purpose of this paper is to find out if and to what extend decentralized urban rainwater harvesting on a household level can contribute to the domestic water supply. The physical potential of urban RWH will be determined and its socioeconomic boundary conditions will be analyzed with the aim to figure out if urban rainwater harvesting could be a feasible addition to the current water supply system of Hyderabad.

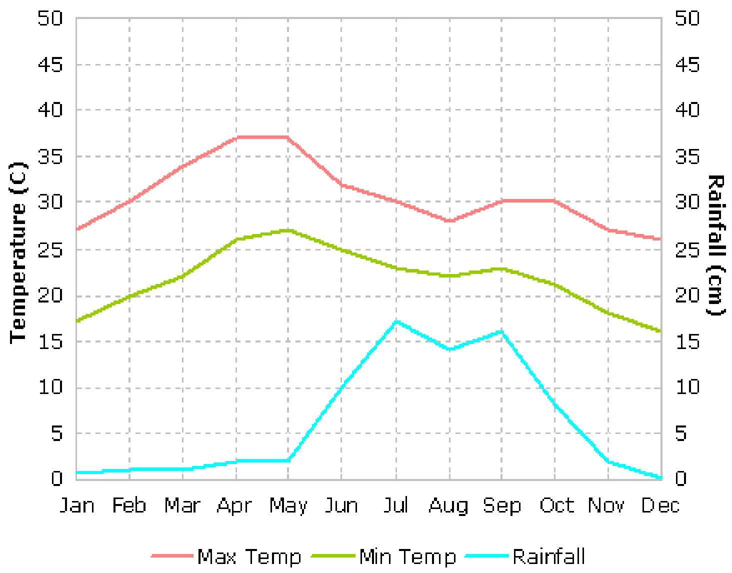
Background

To evaluate rainwater harvesting as an alternative or addition to the domestic water supply system, it is important to understand the physical and socio-economic boundary conditions of situations and locations where the technique will be potentially applied. The following chapter will therefore display general facts about Hyderabad´s urban composition, its climate regime, its domestic water supply system and finally about different aspects of rainwater harvesting.

Geography

Hyderabad, located between 17°19’ and 17°30’ north latitudes and between 78°23’ and 78°32’ east longitudes, is the capital of the State of Andhra Pradesh and with over six million inhabitants the fifth largest city in India (Chapligin2007). The city is located in the Krishna Basin on the Deccan Plateau and has an altitude range between 487m and 610m above sea level. The Musi River, one of the main feeders of the Krishna River, crosses the city from west to east and divides it into the old part of the town in the south and a newer part in the north. The predominant religions and ethnic groups in the city are Hindus (55.40%) and Moslems (41.17%) but also other religions like Christianity (2.13%), and Sikhism (0.2%) Jainism (0.4%) can be found (APSMFC 2010). The Hyderabad District lies in the semi-arid region of the Deccan Plateau and has a tropical climate (warm/dry). May is the hottest month with a mean daily maximum temperature of 39.60 C and December is the coldest month with a mean minimum temperature of 13.60 C. About 78% of the rainfall is received from the south-west monsoon in the rainy season from June to September. The relative humidity ranges between 70% and 80% during the monsoon and 30% to 35% in the summer months (Chapligin 2007). Figure 1 shows the annual average temperatures and precipitation.

Figure 1 Monthly average temperature and rainfall in Hyderabad



(Source: www.weather.com)

One thing which distinguishes many big cities in developing countries from cities in developed countries is the existence of slums. Leopold (2006) states that in 2006 of 6 million inhabitants, "[...] approximately 2 million are slum dwellers, hundreds of thousands of which reside in informal settlements wherever they can find space. A significant portion of these individuals and families hold no legal rights to the land on which they reside, and are therefore not entitled to even basic service provision such as water connections, electricity, or sewerage." BHUMI, an NGO working in the slum areas of Hyderabad, counted that 800 notified and over 1000 unregistered slums are distributed all over the city. Typologies used and numbers stated differ from one institution to another, but in any case, notified slums are often older than un-notified ones (BHUMI 2010 personnel communication). In particular they have a wider legitimacy, which enables them to claim for urban basic services. Municipality is supposed to supply them with water, street lighting, cleaning etc. Range of services for un-notified slums is of lower quality, since they are conceived with the aim not to be permanent. Huchon and Tricot (2006) notice, that no slum has been notified in whole Hyderabad since 1994.

Notified slums inhabitants are more willing to invest in the arrangement of their space, because they do not fear to be evicted. Houses or huts have often strengthened walls. Some of the older slum areas are very difficult or almost impossible to distinguish from lower middle class areas just by their structure. So the term slum can describe very different urban realities in Hyderabad. The average income of a Indian slum dweller is 13

INR per day. (Worldbank 2006). Since there is very little literature about the hyderabad middle class in particular the following lines refer to the Indian in general.

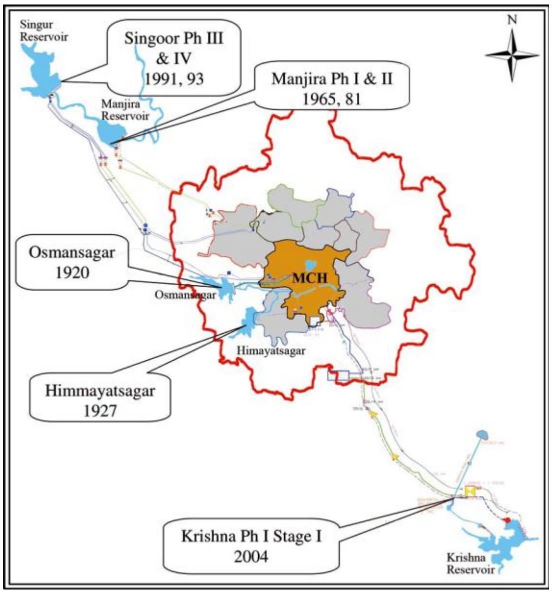
The rich and the poor combined far still outweigh the Indian middle class but it is the fastest growing segment of the population. (Deutsche Bank Research 2010). Of an Indian average middle class family 71% own properties, but only 9% have a mortgage, 19% own cars, 100% of households have TVs, and 91% have mobile phones . The average income of a Indian middle class citizen is between 80 and 150 INR per person per day.

Household savings are low at 13% of annual income; mainly to meet emergency needs, health care and education costs.(CSLA 2010)

Water Supply

In the past, Hyderabad's water supply was based on its natural and man made water bodies. Until 1973, the Hyderabad region had 932 lakes and ponds of which many were fit for drinking water supply. By 1996, 18 lakes of greater than 10 hectares and 80 smaller water bodies, totaling over 8 km^2 of surface area, had been completely lost, and the vast majority of the remaining 834 were severely polluted and drastically reduced in size as well. (Leopold 2006) To meet the water demand of its rapidly growing population, new sources had to be found, so nowadays the bulk of the water supply is based on long distance water supply.(see figure 2)

Figure 2 Water supplies in Hyderabad



(Source: MCH 2006)

The Hyderabad Metropolitan Water and Sewerage Board (HMWSSB), which was established in 1989, is the body responsible for “planning, design, construction, implementation, maintenance, operation, billing and relations with the end users” concerning Hyderabads water supply (Huchon &Tricot 2007).

Hyderabad’s current estimated demand stands at 1100 Mega Liters per Day (MLD) which splits into 1000 MLD from all reservoirs and 100 MLD from Groundwater extractions. However, its installed capacity is merely 930 MLD, and this is made worse by drought conditions that constrict supply even further. As shown in table 1 a huge gap is indicated between current supply and demand, and this is likely to widen by 2021, when the estimated demand will grow to 1500 MLD. (MCH 2006) To address this deficit the Hyderabad Metropolitan Water Supply and Sewage Board (HMWSSB) is planning to build further barrages at the Krishna reservoir. At the time of this thesis, the first barrages are already operational but could not been considered because no data was available yet.

To overcome supply shortages, many households, businesses and industries fall back on groundwater reservoirs. The number of bore wells increased to over 40 000 private and public bore wells. But due to discharge of untreated industrial effluents over decades the groundwater quality is very poor and is considered as not potable. Leopold 2006 states that the groundwater is contaminated “[…] at levels exponentially higher than what is considered safe by international standards such as arsenic, calcium, chlorides, lead, magnesium, selenium, sodium, and strontium.”

Table 1: Deficit in Supply for Different horizon years

Year	Projected Population (in Millions)	Water Demand (in MLD	Present Water Availability (in MLD)	Deficit (in MLD)
2011	7.72	1200	1000	200
2016	9,3	1200	1000	200
2021	10.9	1500	1000	500

(Redrawn from MCH 2006)

While the lack of availability of clean water makes the water supply of Hyderabad a difficult task, the problem is compounded by the distribution network with its insufficient infrastructure.

Parts of the distribution network especially in the old city, is old (60-70 years) and the pipelines are often corroded resulting in breakages and leakages (Johnson, 2004). 33% of the domestic water gets lost due to leakages and illegal connections. The existence of these illegal connections is one indicator for the insufficient supply situation in Hyderabad. Another factor which affects the quality and quantity of the domestic water is the alternate day supply. Because people collect more than the required amount to be on the safe side and dump the potentially remaining volume when refilling the next time, the water consumption is higher than actually needed. Furthermore, an alternate day supply amplifies the effect of corrosion by letting air into the pipelines. Equally, a negative pressure is created by open taps when the pipes are already empty, which leads to additional contamination by sucking in water from outside of the pipes in case of leakages. The proximity of water and sewage pipelines, which have leakages as well, worsens this problem. (Chapligin 2007)

Especially in slum areas the domestic water supply situation is critical. Ramchandraiah 2007 notes that, ”Intra-city inequity in water supply as an issue has not been addressed by the policy makers.” and that “ as a result, people in such areas fall victim to water-borne diseases”. Slum dwellers don’t have the economic resources to react to water shortages, like ordering private or public water tankers or buying mineral water. This is why an analysis of the appropriateness of rain water harvesting has to distinguish between middle class and slum households.

Rainwater Harvesting

The annual average rainfall in Hyderabad is about 700mm per year, the MCH area is about 170 square kilometers. The amount of rainfall every year on Hyderabad’s MCH area is 118000 Mega Liters per Year (MLY) which is equivalent to 32300 Mega Liter per Day (MLD). The overall installed supply capacities of all reservoirs are 930 MLD. So the amount of rain fall in Hyderabad is more than thirty times the amount the city gets supplied with from the reservoirs. And this is just the rain falling in the MCH area which is less than 20 % of the GHMC area. The question is what happens with these clean, unpolluted water masses falling every year in Hyderabad.

In a densely populated urban environment like Hyderabad, unsealed surfaces get more and more replaced by urban infrastructure like buildings and streets. Therefore the amount of surface area which is able to let the water infiltrate through the soil layers is very limited and so, natural recharge gets diminished. Most of the rainfall is conducted through Nalas (channels) into the Musi River and then out of the city. Hence, just a very small amount of the rainfall accounts for the city’s water supply.

The idea of urban rainwater harvesting is to capture and use this water directly where it falls. There are different concepts and techniques of rainwater harvesting. A common and one, partly used in Hyderabad, is artificial groundwater recharge. With this method rainwater falling on the roof or paved area is carried through pipes and gutters into recharge wells and percolation pits from where it drains into the ground water. In dry periods or whenever required this water can be used again by using bore wells or groundwater pumps. In regions where most of the rain falls during a few months like in Hyderabad, this method appears very attractive because it allows using the groundwater aquifers as huge, gratis, conserving storage vessels. The problem in Hyderabad is that the soils have a very low filtering ability and that the groundwater bodies are polluted by industrial and domestic effluents resulting in non-potable groundwater.

Another approach is to save the rainwater in tanks for direct use. This method is applied in the private sector. Because the catchment area is mostly the roof, it is called roof top rainwater harvesting or storage systems. With this method, rain water gets collected, falling on the roof through a pipe which goes down directly or through a filter unit into a storage tank or service well. With this method it is possible to create an additional source of potable water. The use of a rooftop rainwater harvesting system is limited physically by three factors. By the amount and distribution of rainfall, by the size of the catchment area respectively roof area and the size of the storage vessel. In Hyderabad most of the rain falls from June to October. That means during the dry season there is no inflow into the storage facility. A comparatively big catchment area with a rather huge storage tank would be necessary to assure water supply from a rooftop rainwater harvesting system the whole year through.

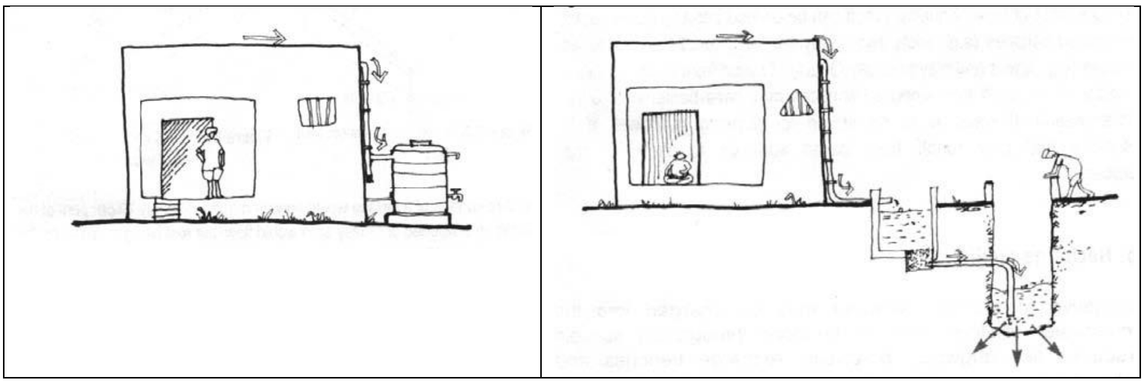
But, even if a supply during the rain-laden months with water is secured, this could mean a substantial improvement. As mentioned above water pipes often suffer from breaks and leakages which together with periods of under pressure in the pipes lead to the contamination of the tap water. This contamination is considered to be worse during the monsoon season. When it rains heavily many sewage channels overflow and effluents get sucked into the tap water pipes. This causes regularly water-borne diseases like diarrhea, enteric fever and viral pyrexia/fever. Especially inhabitants of slum areas suffer from these water-borne diseases. Ramchandraiah (2007) states that, ”Diarrhea and viral pyrexia/fever are the two major causes of hospitalization of the poor in the city” Further on he underlines these diseases are widely spread in slum areas due to a“[...]lack of clean drinking water, poor sanitation and low resistance”. Hence providing poor people during the monsoon season with cheap clean drinking water could make urban rainwater harvesting a useful addition to the existing water supply system. The question is how much water a slum or lower middle class house could harvest and what the costs for it would be. These are the major questions the following analysis refers to.

Groundwater resources in Hyderabad are intensively used. 1000 public and 40.000 private bore wells withdraw 95 mega liters every day (MCH 2006). Although some places show rises in groundwater levels, a general downward tendency in the city area is observed amongst others from the central ground water board. This trend can be seen in practice when looking at the time-bound development and establishment of different types of wells, showing that bore well structures have changed and have been dug deeper and deeper in the last ten years. (Chapligin2007). Further on, the cities drainage facilities are not capable to handle the water masses during strong rain events which cause every year severe floods during the monsoon season. To ensure a sustainable development of the cities groundwater availability and its potential as a resource for the domestic water supply, the groundwater recharge has to be higher or at least equal to the utilization.

We have seen both concepts of rainwater harvesting, direct rooftop RWH and artificial ground water recharge, have different pros and cons. The direct use allows water supply only during the rain laden months, and the artificial groundwater recharge is not applicable for drawing potable water because the groundwater is heavily polluted. In the context of Hyderabad a combined approach would make sense. A RWH structure which allows the direct use of rain and leads the overflow into the ground could provide potable water during the rainy season and refill and dilute the polluted and intensively used ground water aquifers for non drinking purposes during the summer.

That is why a rainwater harvesting system where both concepts are combined is suggested and the following calculations and analyses will be made for such a system.

Figure 3 Rain water harvesting systems



(source: www. cseindia.org)

Rainwater Harvesting in Hyderabad

There has been a strong rainwater harvesting movement in India for quite some years. Many NGOs are advertising the advantages of RWH in urban and rural environments and there are also some governmental programs on rainwater harvesting. In Hyderabad the Andhra Pradesh Water, Land and Trees Act (APWALTA) from 2002 made it mandatory for new buildings with a plot size above 200 m2 to construct rainwater harvesting structures. According to HMWSSB, over 90000 RWH structures where implemented in the GHMC area. These structures are without exception artificial recharge structures like trenches and percolation pits (Chapligin 2007). For the Hyderabad specific shortcomings of this kind of RWH see above. Even though there are efforts made from Hyderabads authorities to implement and promote RWH, there is a poor response from the private sector when it comes to invest in RWH technologies (Times of India 2009). This is due to different reasons. The most important one is the lack of good incentives. The Andhra Pradesh Revised Building Rules (2008) offer a ten percent reduction of the property tax if a RWH structure gets installed. If a new building with a plot size above 200 m^2 does not install a RWH facility a sanction of 10% additional property tax gets remitted. These regulations fail to set an useful incentive, especially for low and middle class households. Because the incentive is bound to the property tax the benefits for house owners with small plot sizes would be marginal (Rao 2010 personel comunication). Another reason for the poor response is that no definition of the size nor the composition is mentioned in the regulation, which means that for example with a big plot size of 10000m^2 one small percolation pit would be enough to get the property tax reduction and avoid the sanction. This problem gets amplified by the lack of law enforcement. The Hyderabad Metropolitan Water Supply & Sewage Board (HMWSSB) is responsible for the water supply and provides with its 2001 installed Rainwater harvesting cell information and help concerning RWH. The Municipal Corporation of Hyderabad (MCH) on the other hand is taking care of the storm water runoff and is giving the subsidies, and the Hyderabad Urban Development Authority (HUDA) is responsible for construction supervision. This fragmented structure of authorities leads to the fact that a rainwater harvesting related site inspection is not done. Hence it is questionable if all reported facilities are really implemented (Rao 2010 personnel communication).

Methods

To answer the research question, if and to what extend urban rainwater can contribute to the domestic water supply and to the solution of Hyderabad's water crisis, certain information is required. In this chapter I will present the methods which have been applied to obtain this information.

Literature research

In the beginning of this study a literature research has been conducted. Different databases and the Internet have been searched for topic related articles. Especially the data base of the Sustainable Hyderabad project of the Potsdam Institute for Climate Impact (PIK) was the source for many articles. Google scholar has been used as search engine to find more relevant information. Search terms have been: Hyderabad water supply, water supply mega city, Hyderabad rain water harvesting, Hyderabad water, Hyderabad water pricing, Andra Pradesh water pricing, Rainwater harvesting, Urban rainwater harvesting, Rain water harvesting India, Income Hyderabad, Minimum wage India, Slum Water Supply.

Survey

To get an overview on the physical and socioeconomic boundary conditions for rain water harvesting, a survey was done during a field trip from August to October 2010. English is the second official language in India and widely spoken on a very good level but it was assumed that the level of education and so the level of English in the lower income areas was not sufficient for a semi structured interview. That is why the interviews have been conducted with an interpreter, who translated from English into Telugu. All surveyed areas cover at least partly slum structures. In some areas only slum households have been interviewed, in others only middle class and in some areas both. The areas were selected based on the local knowledge of Mr. Phillip Kumar who lives and works in Hyderabad as a social scientist, and who is very experienced in planning and conducting surveys in Hyderabad (Kumar 2010, personnel communication).

Figure 3 surveyed areas (red: slum dominated, green: middle class dominated)

Semi Structured Interviews

In the survey 80 lower income households (less than Rs 40,000 per annum) were interviewed (NCAER 2010). Half of the households were slum households the other half in lower middle class . One important aim of the interviews was to gather data to quantify the physical potential of RWH. Physical potential means in this case the amount of water a RWH facility could potentially provide over the year. Another task was to understand the actual supply situation and socioeconomic boundary conditions of the water supply from a household perspective. The introduction of the interviews has always started with a non-water related question to avoid bias. There have been a number of core questions which have been asked in each interview.(see Annex 1). Many of the questions have been asked in an open manner to provide the opportunity to get information somewhat beyond the assumed dimensions of answers.

To get information on the physical potential of RWH, following parameters where determined during the interviews:

Roof area / inhabitant ratio – The roof areas have been inspected during the interviews and their sizes were estimated. The roof area inhabitant ratio results from the size of the roof and the number of inhabitants which has been enquired during the interviews. This is one of the most determining factors for the physical potential. Because of the high importance of this parameter the roof sizes have been verified by using satellite imagery to minimize the error in this data.

- Roof material / structure has been inspected and assessed during the interviews. This information is mainly important for the installation of RWH structures.

- Storage capacities – The storage capacities already existing in the household have been enquired and inspected during the interviews to know how much storage capacity already exists and could be used for RWH.
- Space for additional storage capacity – This is an important information when it comes to implementing RWH. Slums and lower income areas are usually densely populated and space is rare. Hence the respondents have been asked if they would have space for additional storage capacity.

To get an overview on the socioeconomic boundary conditions the following parameters were determined:

- Sources of supply – To assess the current supply situation in slum and middle class areas, all respondents have been asked from which sources they draw their water and how much water they get from which source.
- Satisfaction of water supply – Further on the inhabitants have been asked ask if they are satisfied with the current supply situation, to recheck if there really exists a supply problem from the household perspective and how the perception of the water supply situation is.
- Water related problems – All respondents have been asked about potential water related problems to get an overview what kind of problems exists, and which are the most common important ones.

The answers have been coded and statistically analyzed in MS Excel.

GPS Monitoring and Remote sensing

The locations of the interviews have been recorded with a QSTARZ BT-Q1000X GPS Data LOGGER. The recorded data was processed with the software Photo tagger. Photos of typical housing types of the respective area were taken and also located with the software Photo tagger. The roof areas were inspected during the interviews and their sizes estimated. To get more precise data the exact sizes of the roof areas were determined by using satellite imagery from Google earth. The respective roof areas were identified via GPS on the satellite imagery and measured with the area measure tool in Google earth. This data was checked with the values estimated in the field.

Micro water balance model

To quantify the physical potential of RWH a micro water balance model was programmed in Microsoft Excel. This model uses rainfall data from 1997 to 2007 from the xDat (eXtensible Database Access Tool) of the Potsdam Institute for climate impact research to calculate the potential amount of rainwater which could be harvested for two different typical household types. The model consists of the following equation:

$$L_{d+1} = \begin{cases} if\left(L_d + P_{d+1} \cdot B - E < 0\right): 0 \\ else \quad : \begin{cases} if\left(L_d + P_{d+1} \cdot B - E > K\right): K \\ else \quad : L_d + P_{d+1} \cdot B - E \end{cases} \end{cases}$$

$$U_{d+1} = \begin{cases} if\left(L_d + P_{d+1} \cdot B - E < K\right): 0 \\ else \quad : L_d + P_{d+1} \cdot B - E - K \end{cases}$$

L= Water level [l]: amount of water in the storage vessel

P= Precipitation [mm]

E= Withdrawal [l/day]: the amount of water which gets withdrawn everyday out of the RWH tank

K= Storage Capacity[l]: the Volume of the storage vessel

B= Catchment area [m^2]: size of the roof

U= Effluence [l/day]

All parameters have been derived from the results of the survey. The outcome of the model shows the annual distribution of water availability from a rain water harvesting facility and the amount of effluence. It allows seeing in which part of the year people could draw which amount of water from a RWH facility.

Cost Benefit Analysis

To evaluate a RWH construction from an economic perspective it is necessary to quantify the potential economic benefit. For this purpose the investment and maintenance costs have to be contrasted with the economical value of the harvested amount of water from a RWH structure. Therefore a random market survey was conducted to get information about these costs. Several sellers of water tanks, pipes and filtering systems where contacted via email or phone and a inquiry was made concerning the prices of the respective items. The base period for the calculation assumes a minimum durability of 10 years for all items.

Results

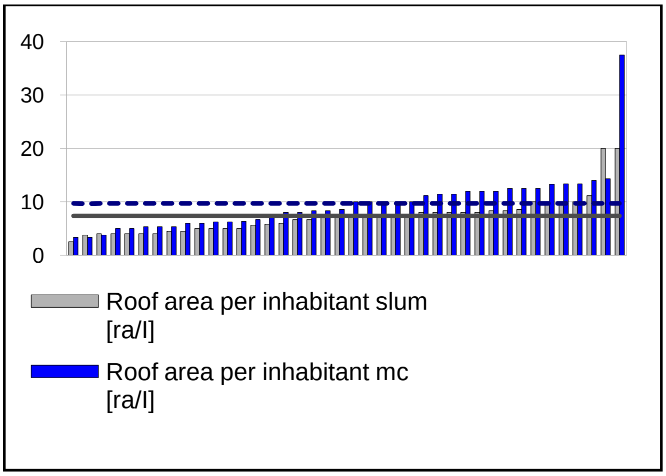
Survey

As mentioned above a survey was done to get an overview on the socioeconomic and physical boundary conditions. This chapter will display the results of the survey.

Roof Area / Inhabitant Ratio

The two mayor determining factors for the physical potential for a rain water harvesting structure are the size of the catchment area and the size of the storage capacity. As we talk in this case about roof top rainwater harvesting, the size of the roof area is one very important aspect. Another factor is how many people get supplied by the catchment area. Figure 4 shows the ratio between inhabitants and roof area.

Figure 4 Roof area inhabitant ratio



The range of values for slum households is 2.5m² ra/I to 20m² ra/I. The range for middle class household is from 3.3m² ra/I to 37m² ra/I. The average value is 7.34m²ra/I for slum households and 9.65m² ra/I. It is remarkable that the values between slum and middle class households do not differ very much. This is due to the fact that a high fraction of middle class households are located in multistory buildings and slum households mostly in one storey buildings.(see Figure 7)

Figure 5 Distribution of roof area per inhabitant

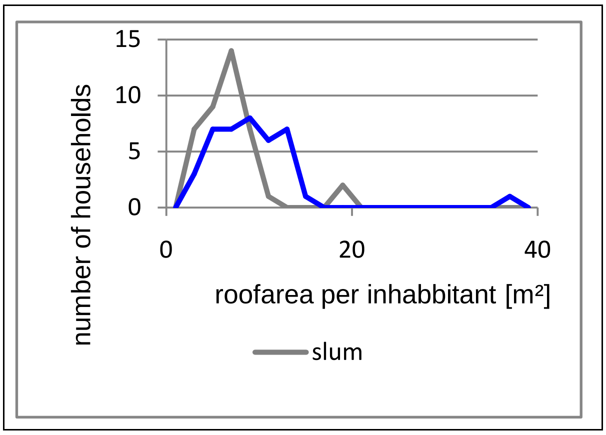


Figure 5 shows the distribution of roof area per inhabitant among the interviewed households. The majority ranges between 2 m² and 11 m² for slum dwellers and 2 m² and 15 m² for middle class households.

Housing Types

During the field work 4 different kind of housing types have been identified. Figure six shows exemplary pictures for these different housing types. Type one buildings were only found in slum areas. They were mostly made of iron sheet walls and or improvised walls with loose bricks, clay or plastic bags. These buildings are highly exposed to weather conditions. They have a low insulation and are vulnerable to floods and storms. Types two, three and four are similar in their building structure. In most cases they are constructed a reinforced concrete scaffold which is filled up with bricks.

Figure 6 Housing types

Type 1: Not solid building

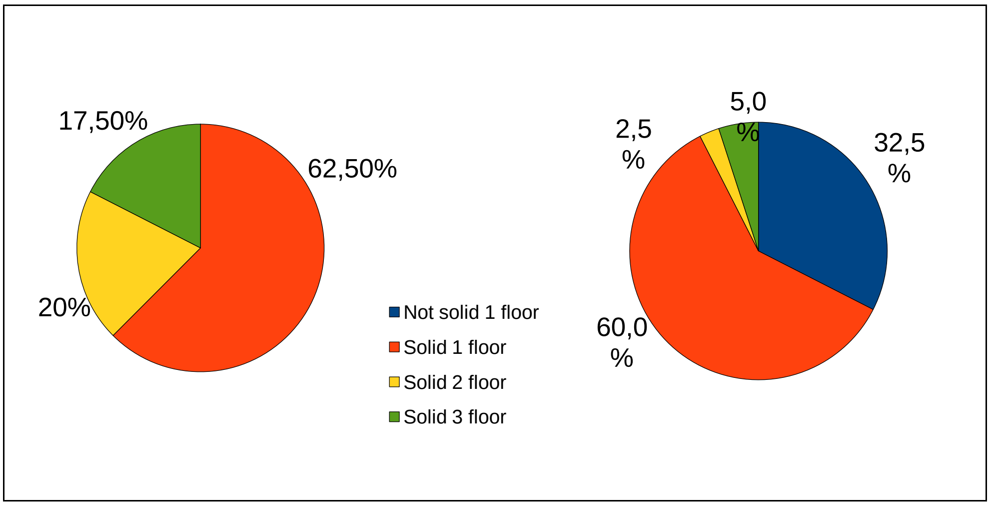
Type 2 : Solid building 1 floor

Type 3: Solid building 2 floors

Type 4: Solid building 3 floors

Figure 7 show the distribution of different housing types in slum and middle class areas. The most prevalent housing type in middle class and slum areas is type two. Not solid buildings are only found in slum areas (32%), multistory buildings are rare in slum areas (7.5%).

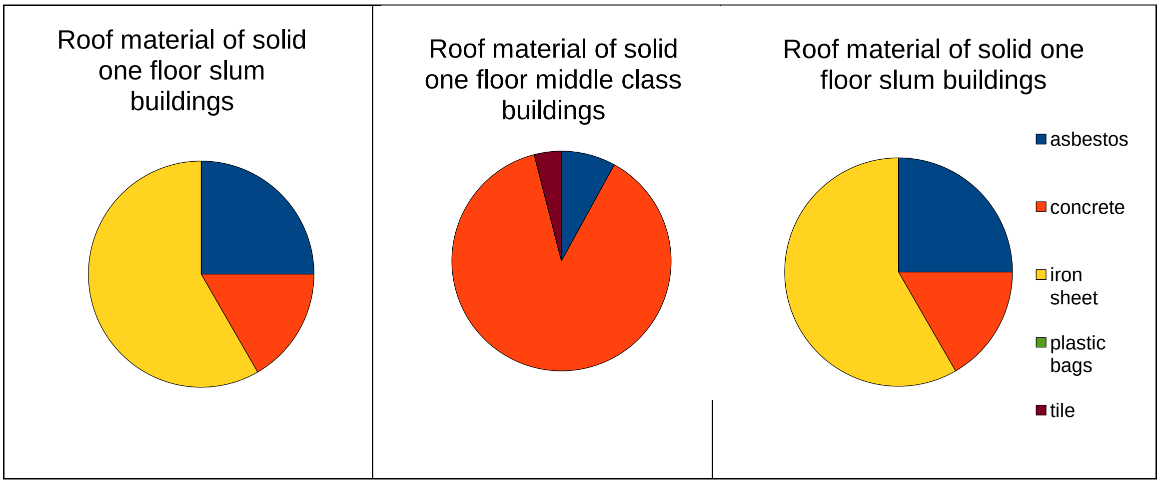
Figure 7 Housing types middle class / slum



Roof Structure

The roof material and the way the roof is constructed, plays an important role when it comes to the constructional planning of a roof top rainwater harvesting facility. All sighted houses had a flat roof or a roof with a low inclination. The two and three floor buildings have all reinforced concrete roofs. The not solid and solid one floor buildings have reinforced, concrete, iron sheet or asbestos roof tops. Figure 8 shows the distribution of different roof materials for one storey buildings in slums and middle class areas.

Figure 8 Roof materials for one floor buildings in slum an middle class areas



The inspection of the roof tops showed that in slum areas the most used roof material is iron sheet (66%) probably due to its low constriction costs. In middle class area the dominating material is reinforced concrete (82%). Most of the reinforced concrete roofs are surrounded with an armor which leads the rainfall through one or more pipes to the street. The iron and asbestos rooftops are constructed with a low inclination which allows the Rainwater to run off.

Storage Capacities

Another important boundary condition for Rainwater harvesting is the ability to store water. Because the households had to adapt to the prevailing insecure alternate water supply, all of them store water to bridge the regular supply gaps. There are different ways and bins to store water. The following gives an overview about the existing storage tanks and capacities.

"Bhindi" (Plastic or steel jug)

Bhindis are the most commonly used bins in the interviewed households. They are used for storing drinking water, fetching water from bore wells or public stand posts. One household owns averaged 10 to 15 bhindis. The volume of one bhindi is between 6 to 12 liters (Figure 9).

Figure 9 Different Bhindis

Figure 10 Small sump

Figure 11 Plastic „Drums“

Figure 12 Plastic tanks in Rasolpura

“Drum ” (plastic barrel)

These plastic barrels are used to store water for non drinking purpose. The volume differs from 150 to 200 liters. A single household owns an average of 2 drums (Figure 10).

Sump

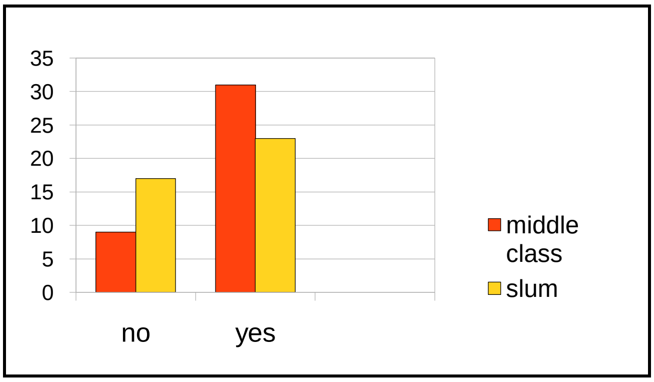
Sumps where only found in very few households (4%). In the majority of the cases they store the alternate coming tap water. The storage capacity of the found sumps differs from 300 to 3000 liters (Figure 11).

Tank

Water tanks are used by 9% of the interviewed households. They are used to store tap water or water which gets delivered by water tankers. The volume ranges from 1000 to 3000 liters(Figure 12).

Space for Additional Storage Capacities

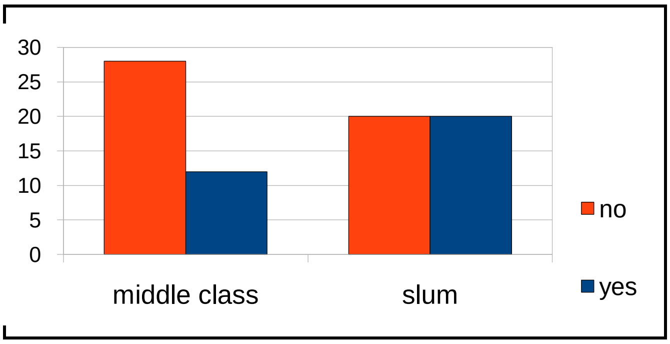
Figure 13 Space for additional storage capacity



The limiting factors for the existing or planed storage capacity are the costs and the space which is required. The investigated areas, especially the slum areas are densely populated so space is rare. In the interviews people were asked if they have space for an additional 2000 respectively 3000 liter tank in their house or on their plot. Figure 13 shows, that even though the space is limited most of the households would have enough space for an additional tank.

Use of Rainwater

Figure 14 Use of rainwater



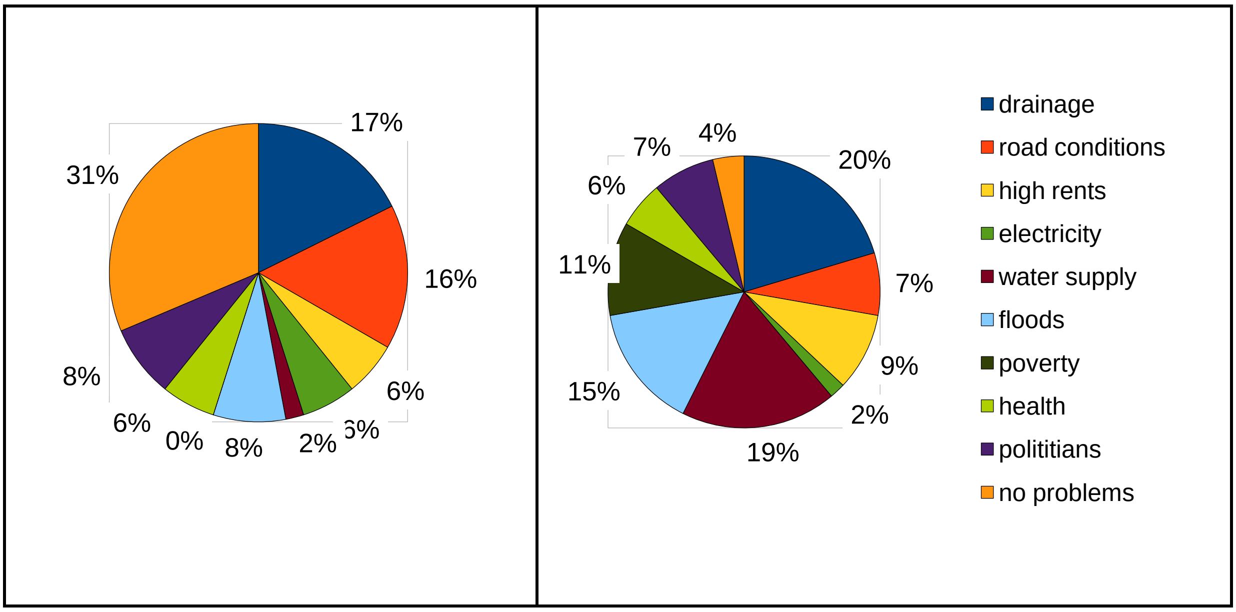
Another task of the survey was to find out if the people already use rainwater and if they do how they harvest it and for what purposes it is used. Half of the interviewed slum households and more than one quarter of the middle class households are using rainwater.(see figure 14) In all cases the water is used for toilet, washing and cleaning purposes. The rainwater is gathered simply by buckets or bhindis under the roof.

Water related Problems

To evaluate rainwater harvesting as a possible option for slum and middle class households to enhance the water supply situation it is indispensable to have a look at the current domestic water supply. Sources of supply, water related problems and costs for water supply where objects of the survey. All the results of this chapter have to be taken with care because the interviews were taken during the monsoon season and the answers maybe would have been different during the dry season.

In the beginning of every interview the respondents were asked to name the major problems in the neighborhood. Up to this Time the respondents did not know the purpose of the survey to avoid biases in the responses. This first opening question had the purpose to find out if water issues are really one of the major problems in lower income neighborhoods.(see figure 15)

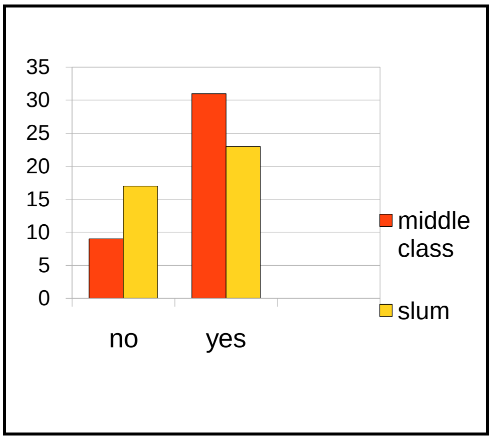
Figure 15 Major problems slum (left) / middle class (right)



As figures 15 shows, water supply is only in the slum households considered as a relevant problem (19% in slums 2% in mc areas). But the insufficient drainage system and floods are affecting both neighborhoods.

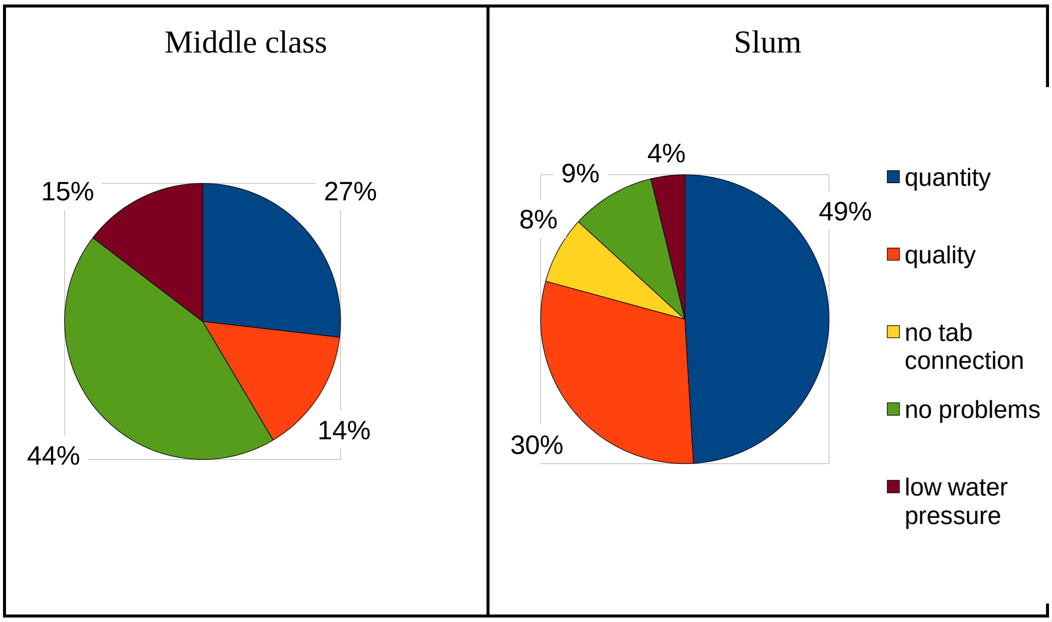
All interviewed households where asked if they are satisfied with the domestic water supply. Figure 15 shows that two third of all interviewed slum households are not satisfied. More than half of the middle class households are satisfied with the domestic water supply (figure 16)

Figure 16 Satisfaction of the domestic water supply



The respondents were also asked what the problems related with the domestic water supply were. Almost half (43%) of the middle class households have no problems with the domestic water supply. The most named weakness of the current water supply situation is the lack of sufficiency. Almost half of all slum and households and more than a quarter of the middle class households lament the insufficient amount of water delivered by the domestic water supply. Water quality is more a concern of slum households, more than one third lament bad water quality, middle class households much less. Other water supply related problems where the absence of tap connection in slum areas and low water pressure, which plays a more important role in middle class households.

Figure 17 Problems domestic water supply



Slum households are affected to a greater degree by poor water quality because of different reasons. In the visited slum areas a lot of tap water pipes suffer high leakages due to illegal connections. These leakages cause water losses and contamination. Because of the alternate day supply the pipes are not always filled with water. A negative pressure is created by open taps when the pipes are already empty, which sucks water from outside into the pipes. The direct proximity of water and sewage pipelines, which have leakages as well, intensifies this problem. Especially during the Monsoon season is this a major cause for polluted tap water. (Chapligin 2007)

Water Consumption

To determine to what extent rainwater harvesting can enhance the water supply situation, it is necessary to know how much water is consumed by the households. During the interviews the respondents were asked how much tap water they use every day. The margin of inquired values is very wide. In slum areas the minimum value is 3 liters per capita per day, the maximum is 30 liters per capita per day. The average is 10.7 l per capita per day. Interestingly the values in middle class areas differ not as much as expected. The average daily amount of available tap water in middle class areas is 12.3 l per capita per day. The range of values is between 5 and 30 liters per capita per day. These numbers differ a lot compared to the data found in literature. According to Trichon and Ico (2007) the HMWSSB assures 58 l per capita per day from the domestic water supply system. In Shaban (2007) the overall water consumption in slum and lower income areas is 90 respectively 81 lpcd. One reason for this could be that the HMWSSB data includes the water delivered by the water tankers and Shaban (2007) includes also groundwater.

Micro Water Balance

Exemplary households have been derived from the results of the survey to determine the physical potential of rain water harvesting. The households are described with the following parameters:

- catchment area, which is in this case the size of the roof area
- inhabitants
- storage capacity. The chosen value differs from the average value because it is assumed, additional capacity will be installed for a rainwater harvesting facility.

- daily water consumption, is the amount of water which will be withdrawn every day from the harvested water. It is the same amount the household have currently from the tap.

The first starting point to get values for the parameters was to have a look on the average values. These average values have been compared with the survey data and checked how often they are distributed, to assure that these exemplary households really could be found on the ground. If the average value was not found in the data, the next higher or lower value with a high distribution was used. The values for the storage capacity have been derived from the size of the already existing storage vessels and based on an appraisal of realistic values in terms of space and money done during the site visits.

The parameters named above, have been entered in a micro water balance model. The model uses the rain data from 1997 to 2007 to calculate the potential amount of rainwater which could be harvested.

Household type 1 represents a household which is exemplary for the surveyed slum areas.

Figure 18 Exemplary household slum

<table>
<tr>
<td>Average values:
Roof area: 45m²
Inhabitants: 7.2
Storage capacity: 700 l
Daily water consumption 10.7 l per capita per day

Chosen values:
Roof area: 40m²
Inhabitants: 7
Storage capacity: 1000 l
daily water consumption 75</td>
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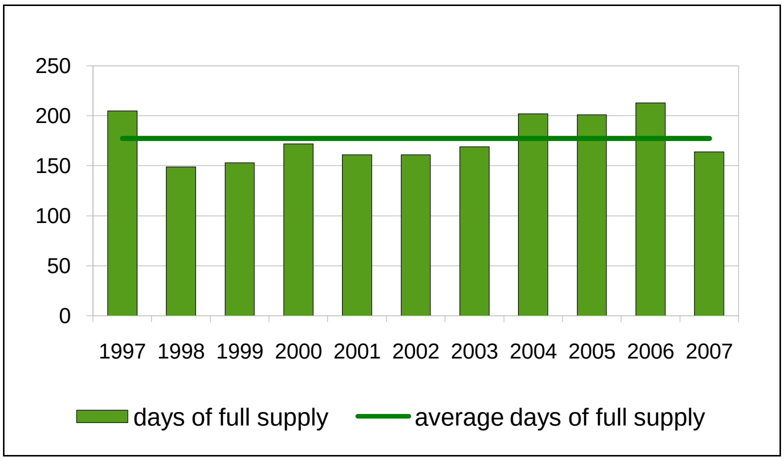
</table>

Figure 19 Days of full supply slum



The figure 20 shows the number of days where the household could withdraw the full amount of 75 l of water. The mean value is 177 days; the minimum is 149 days in 1998 the maximum is 213 days in 2006. The mean value would increase to 205 days if a storage capacity of 2000l would be installed.

Figure 20 Annual water level household slum

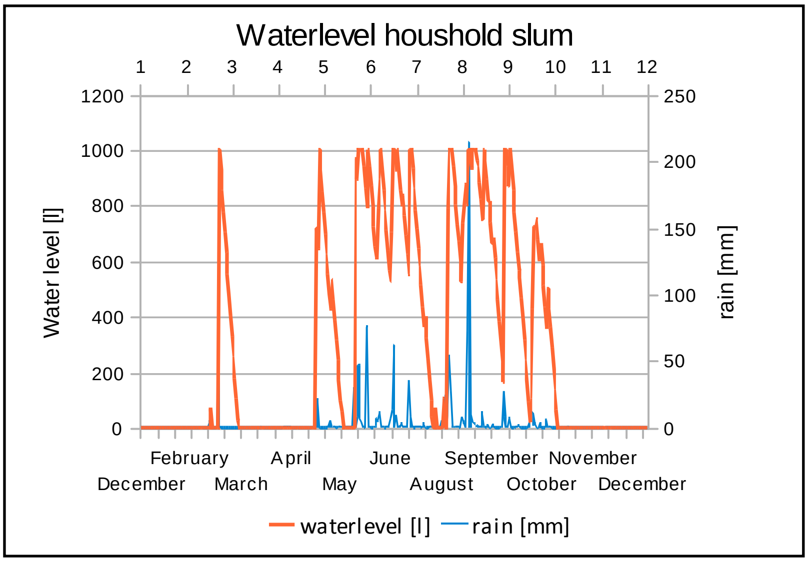
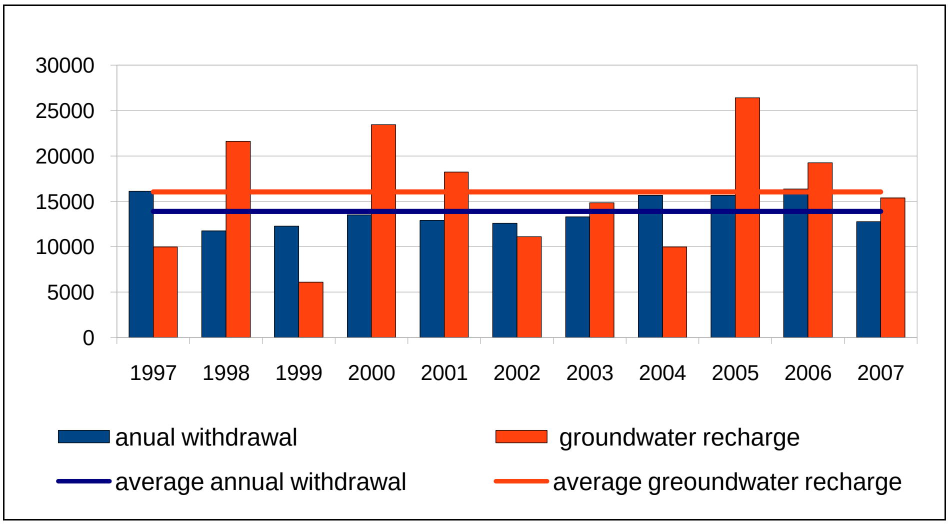


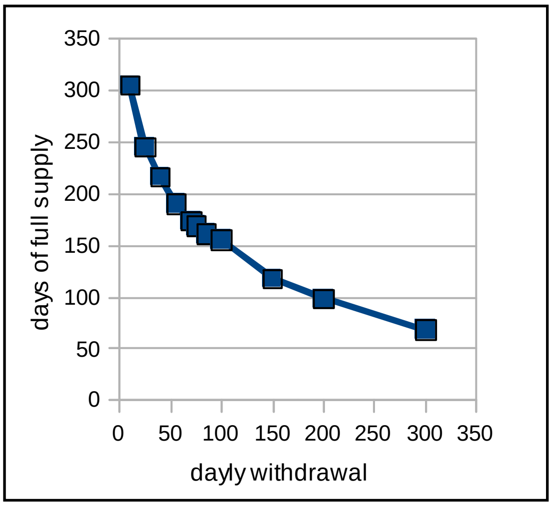
Figure 20 shows the annual rain distribution and the respective water level in the storage vessel for the Year 2000. It shows that a supply of 75 liters per day is secured during the whole monsoon season from April until the beginning of November. In May and August periods of water shortages appear. The rainfall data of the year 2000 have been used because it was closest to the average rainfall during the10 year time frame.

Figure 21 Annual withdrawal and groundwater recharge slum



If Rainwater is used, less tap water and less bore well water have to be used. RWH could take pressure off the overloaded domestic supply system by substituting tap water with rainwater. Figure 21 shows the amount of water which could be harvested every year as well as the amount of water which could be used as artificial groundwater recharge. The average annual withdrawal is 13900 l per year with a maximum withdrawal in 1997 with 16100 l per year and a minimum in 2002 12100 l per year. The average annual groundwater recharge is 16000l per year.

Figure 22 Days of full supply / daily withdrawal ratio slum



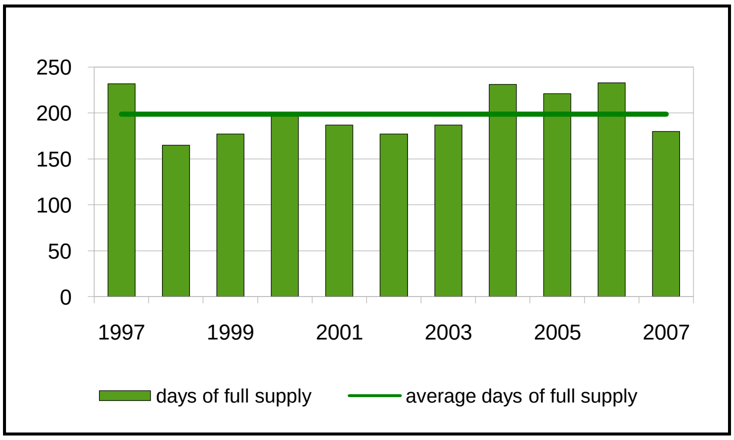
In figure 22 the number of days of full supply is put in relation with the amount of water which is withdrawn every day. The more water is withdrawn every day, the less days of full supply are available. If the exemplary slum household would withdraw 200l instead of 75 l the number of days with full supply would decrease from 177 to 100 days per year. If it would reduce its withdrawal to 30l, full supply could be available for 245 days.

Household type 2 represents a household which is exemplary for the surveyed middle class areas.

Figure 23 Exemplary household middle class

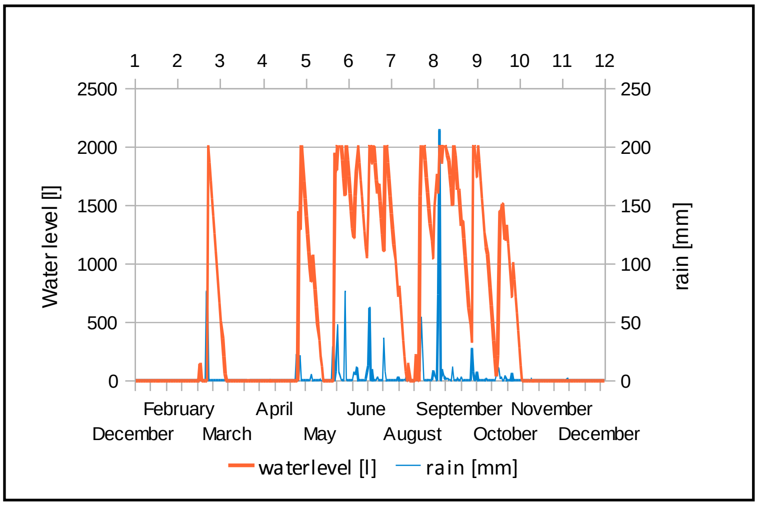
Average values: Roof area: 71m² Inhabitants: 9.2 Storage capacity: 1000 l daily water consumption 12.3 l per capita per day Chosen values: Roof area: 80m² Inhabitants: 10 Storage capacity: 2000 l daily water consumption 150 l	

Figure 24 Days of full supply middle class



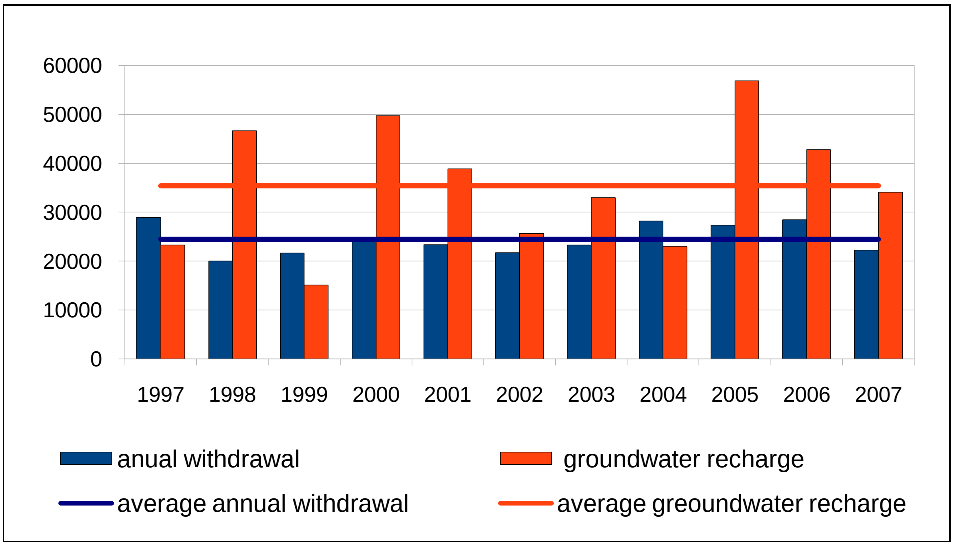
The figure 24 shows the number of days where 150 l water is available. The mean value is 197 days; the minimum of days is 149 in 1998, the maximum 213 days in 2006. The mean value would increase to 226 days if a storage capacity of 4000l would be installed.

Figure 25 Annual water level household middle class



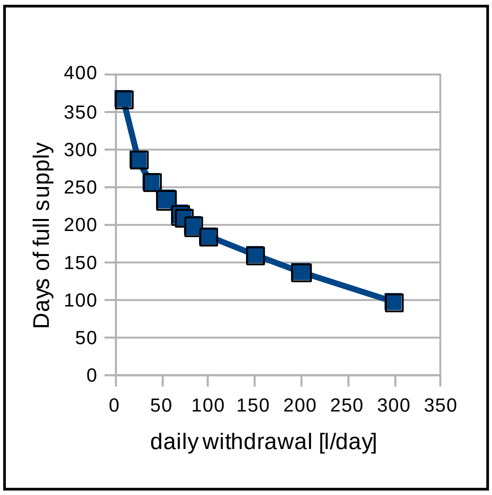
The distribution of days with 150 l water is manly from April to November. As well as for the slum households have to be noticed, that in May and August short periods of shortage may appear.

Figure 26 Annual withdrawal and groundwater recharge middle class



The amount of harvested water as well as the amount of potential groundwater recharge more or less twice as high as observed with the slum household. The average annual withdrawal is 25500 l per year with a maximum withdrawal in 1997 with 28900 l per year and a minimum in 2007 22200 l per year. The average annual groundwater recharge is 35300l per year, which shows that there is still more potential if bigger storage capacities get installed.

Figure 27 Days of full supply / daily withdrawal ratio middle class



The ratio between withdrawal and days of full supply for the middle class households is similar to the calculations for the slum households. Even if the household would use 300 l per day it could have 100 days of full supply, which shows the great potential of RWH.

Cost Benefit Analysis

The last chapters have dealt with the physical potential of rainwater harvesting constructions for different exemplary households. This chapter is meant to transfer this physical potential into economic values and contrast it with the investment, maintenance and running costs for the households (micro-economic perspective). Afterwards the macro-economic and non monetary benefits as well as the respective risks will be discussed.

Description of the necessary Devices (nominal Condition)

The aim is to have a full operational rainwater harvesting structure installed on both house types which will be able to catch the water from the roof, conduct it into a storage vessel and provide potable water. To assure this, both rainwater harvesting constructions should have the following technical features available:

A plastic storage tank. Storage vessels are available in various forms and materials. In this case a plastic tank is chosen because it is the cheapest and in the city already most commonly used vessel to store water. There are many shops and producers in Hyderabad who offer plastic tanks in different sizes and qualities. The storage tank should be closed to prevent mosquito breeding.

Gutters and downpipes. To catch the water from the roof, gutters have to be installed to lead the water through downpipes into the tank. Gutters can be installed as drip molds on roofs with inclination or as small channels on flat roofs. Downpipes are available in different materials and diameters.

A filtering system. A simple mechanic filter is used to remove pollutants from the rainwater. The filter unit is in this case a plastic drum filled with filtering media such as fiber, coarse sand and gravel layers to remove debris and dirt from water before it enters the storage tank. Charcoal can be added for additional chemical filtration. This filtering system can be built domestically and its components are readily available inexpesive.

Percolation pit. As the storage capacities are not able to store the whole amount of rainwater percolation pits are installed to let the overflow soak into to the ground. Percolation pits are filled with pebbles, brick, debris and river sand.

First flush device. The first flush of water from the roof can contain amounts of bacteria from decomposed insects, bird and animal droppings, dust and other for drinking water undesirable components. A first flush device is a valve that ensures that runoff from the first spell of rain is flushed out and does not enter the system. A down pipe with a valve at the end is installed. Inside the pipe a floatable ball is arranged. As the water level in the diverter chamber rises the ball floats, and once the chamber is full, the ball rests on a seat inside the diverter chamber preventing any further water entering the diverter. The subsequent flow of water is then automatically directed along the pipe system to the tank For this device, a minimum design criterion is that the device should divert the first 0.5 mm of the rainfall (Mosely, 2005). To calculate the volume of water needed to be diverted, multiply the length and width of the house or collection surface (in meters) by 0.5 (mm):

Required volume of diverted water (L) = house length (m) * house width (m) * 0.5 (mm) For the chosen buildings, (5m X 8m house size, diverting 0.5 mm rain).

A first flush volume of 0.02 cubic meters i.e. 200L should be diverted. This water can still used sanitation or cleaning purposes.

Costs

The following table lists the investment costs for the different required technical items.

Table 2 Investment costs RWH facility

Item	***Cost***	***Source***
Storage tank	1.5 and 2.75 INR per liter	Own survey
Gutter, down pipes First flush device	110 mm diameter 165.00 INR per meter 200 mm diameter 275.00 INR per meter	Own survey + www.rainwaterharvesting.org
Filter	500 INR	Own survey
Percolation pit (excavation + gravel)	120 INR per m³ in soft soil 180 INR per m³ in rock	Own survey www.rainwaterharvesting.org
Labour costs installation	40INR per hour	Bureau of labour statistics (2010)

Table 3 Investment costs exemplary households

	Exemplary household slum	Exemplary household middle class
Storage tank	2000INR	4000INR
Gutter, down Pipes First flush device	1000INR	2000INR
Filter	500INR	500INR
Percolation pit (excavation + gravel)	300INR	500INR
Installation costs	250INR	350INR
	3950INR	7350INR

Maintenance / Running Costs

The costs for chlorination of the water are the only maintenance cost which will be taken into account. There are other maintenance operations, like cleaning the roof, removing the first flush and cleaning the filter unit but these operation are only to be done once or twice a year or require only a few minutes to do, so that they are considered as low in terms of monetary costs and will be not included in the calculations.

	Exemplary household slum	Exemplary household middle class
Chlorination	200 INR	400 INR

Base period

The base period is the time frame in which the RWH construction is operational without any new investment costs. It is determined by the durability of the technical components of the RWH construction. It is assumed, that the water tank is technical component with the lowest durability of approximately 6 to 15 years depending on the material and how they are exposed to atmospheric conditions (Sivaraman 2003). The base period for all calculations is 10 Years.

Benefits

Micro-economic benefit on household level

The calculations in chapter 4.3.2 have shown that with a construction as described above an average annual yield of 16000 liters for a slum household respectively 25000 liters for a middle class household can be harvested. Because the results of the survey concerning the costs for water are very diverse the prices for domestic water tankers have been chosen as a reference for the water costs from sources other than RWH. 5000 liters delivered by a water tanker cost 300 INR. This means the respective RWH construction could generate an annual amount of water with the economic value of 960 INR respectively 1500 inr.

The following table shows the overall costs and the economic benefit of the RWH constructions over the base period of ten years

Table 4 Costs / Benefits

	Exemplary household slum	Exemplary household middle class
Investment costs	4500 INR	7350 INR
Maintenance costs	2000 INR	5000
Overall costs	**6500 INR**	**12350 INR**
Economic value of harvested water	**7600 INR**	**15000 INR**
Economic benefit	**1100 INR**	**2650 INR**

With a base period of 10 years a rainwater harvesting construction could gain an economic benefit of 1100 INR for the exemplary slum household and 2650INR for the exemplary middle class household. It would take about 7 years until the investment costs amortize. It is very important to notice that the amortization rate depend very much on the running costs. If a household would already have an operational filtering system which could substitute the chlorination, or if they would use the rainwater only for not drinking purposes the investment costs would amortize already after 4 years.

Another benefit on the household level is the increased independence from the domestic supply network. In an environment where the domestic water supply is very unreliable and the groundwater tables have been declining for years an additional water source could help to level out supply gaps and create a higher supply security. Further more RWH could make households less dependent from future water price development. This independence is not only important to level out supply gaps, but also to provide save, clean drinking water which is not assured by the domestic water supply especially during the monsoon season. These effects are difficult to monetize but clearly add to the above calculated benefits.

Communal benefits

Beside the micro-economic benefits rainwater harvesting constructions also create communal benefits. Hyderabad and especially its slums in low income areas are very densely populated. Unsealed surfaces where rainwater can drain into the ground are rare. By leading the overflow through the percolation pits into the ground RWH helps to refill the groundwater reservoirs, which is a intensively used water source for non drinking purposes (Ramachandraiah 2007) Further on rainwater harvesting constructions could possibly have a positive impact on flood reduction. It could function as a buffer during strong rain events if installed in high numbers. This could be very beneficial for slum areas which regulary suffer from urban floods. A Study of Luedeke et al 2010 shows that due to climate change “a relatively certain increase in greater 80mm/day precipitation days until 2050” is to be expected. That means that the risk of urban floods will increase in the future. Rainwater harvesting could work as an adaptation measure to cope with the changing rainfall patterns. As additional, jet mostly unused supply source rain water harvesting can take pressure off the overloaded domestic supply network which could help to make it more reliable**.**

Public Savings

The charges for domestic water supply often do not reflect the real costs. World bank 2001 states that the tariffs for Hyderabad are much lower than the actual production costs. So the domestic water supply is subsidized and every liter which can be substituted by alternative sources lowers the expenditures for these subsidies. The only data which has been found by literature review on unit production costs is from 2001for Hyderabad. To get an estimation of the present prices and costs the data has been corrected with the respective inflation rates from 2001 to 2010 for India. The actual real unit costs may be even higher because the costs for the extension of the Krishna reservoirs are not included in this estimation due to lack of data. The average unit production costs for one m³ water were 0.26 USD in 2001. The tariff for one metered m³ in 2001 was 0.07 USD in Hyderabad (Worldbank 2001). Hence 73% of the costs are subsidized. If corrected with the respective inflation rates from 2001 to 2010 the actual unit production costs are 0.49 USD. Assumed that the ratio of subsidies did not change every m³ of domestic water is subsidized with 0.36 USD which is with the current exchange rate 17 INR.

Table 5 Inflation rates India 2001-2010

Year	Inflation rate
2010	9,468 %
2009	14,966 %
2008	9,701 %
2007	5,512 %
2006	6,528 %

2005	5,566 %
2004	3,785 %
2003	3,719 %
2002	3,198 %
2001	5,157 %

A RWH facility for an average middle class household could save 430 INR subsidies per year, for a slum household 310 INR per year. If this subsidy would be shifted to the households the economic benefit for the household would more than triple from 1100 INR to 4200 INR respectively from 2650 INR to 6050 INR. That means that the investment would amortize already after 4.5 years for slum households and after 5.3 years for midle class households instead of 7 Years.

Risks

Slum Households

One of the biggest problems of implementing rainwater harvesting in a slum area is investment security. Many slum areas in Hyderabad have the status "not notified slum areas", which means that the inhabitant settled the area without having the tenure rights. These settlements can be broached every day if the land owner decides to. In a rapidly growing city like Hyderabad where land prices are exploding, the risk of loosing your house in a not notified slum is a risk slum dwellers face every day. Hence it can be assumed, that the willingness of investing in a technology which is not flexible and mobile, is very low. This is very unfortunate because these areas have mostly no tap connections and sometimes very limited access to public stand posts. Water supply is a burning issue in these areas but rainwater harvesting is probably only suitable for notified slum areas. But also in slum areas where people have a better investment security the willingness to invest in a technology which amortizes after 7 years is questionable. Many people who live in slum areas, especially those who moved from rural areas do not see the slum as their final destination. Many of them only rent the house and see it as one station on a way to a better life. Thus it is disputable to assume, that these people like to invest in a technology which binds themselves for a long time period to a place with very poor infrastructure and living conditions. Another problem are the high investment costs. The average income of a Indian slum dweller is 13 INR per day(

Worldbank 2006). It would take almost a wage of one year of one person to cover the investment costs. It seems very unlikely that a slum household could afford such an investment for a technology which provides drinking water only during the monsoon season

Middle class households

In the surveyed areas most of the middle class households have already strategies to cope with the insecure domestic water supply. Most of them call during times of water scarcities water tankers which deliver 5000l of water for 300 INR. This is a very comfortable and flexible solution because one can fall back on it when needed. This flexibility RWH cannot substitute. Rainwater harvesting could be a substitute only during the Monsoon time. It has to be noticed that relying on tanker is a solution, many households have arranged with well. The results of the survey (see picture 17 and 18) have shown that a lot of middle class people are satisfied with the water supply. Even if a RWH construction for the exemplary household could gain an economic benefit of 2650INR over ten years it is questionable if this is enough to motivate middle class inhabitants to take action. Hereby it has to be noticed that if people depend on water tankers they need a storage vessel for the tanker water as well. So the costs for the storage capacities do not necessarily have to be included in full amount to the investment costs. Assumed that a middle class household already have the necessary storage capacity 4000 INR which are about one third of the overall costs could be saved.

Another impression during the survey was that - in contrary to the slum areas - community problems are less issued and discussed in the community. Problems get solved individually. To give an example, some people complained during the interview that the already low water pressure is decreasing because some of the neighbors connected pumps on their tabs to get more water – a typical individual solution which do not take into account possible negative effects for the community Hence it is unclear if the communal benefits are persuasive arguments for middle class citizens to invest money in RWH.

Conclusion

The previous chapters have shown that rainwater harvesting could contribute to improve the domestic water supply in Hyderabad. It could provide save drinking water during the monsoon, reduce the risks of urban floods, refill the the declining groundwater reservoirs and take pressure off the overloaded supply system. The problem is that the economic benefits are probably not high enough to be an incentive for the people to invest in RWH technology. Many slum dwellers simply just cannot afford the investment costs. To spread rainwater harvesting and make it a common and widely used technique in Hyderabad the government should introduce better incentives (The actual incentives and promotion mechanisms are described in chapter 2.4). If for example the public savings from replacing tap water supply (which is subsidized) by RWH were shifted as subsidies to households with a RWH facility the economic benefits for these household would triple and the investments would amortize after 4,5 instead of seven years. Without additional subsidies Rainwater harvesting will probably not establish itself. These subsidies would make sense for the government in various ways. More decentralized use of rainwater would mean less tankers and less tap water which would take pressure off the supply system and avoid costly extensions of the existing centralized supply system. Furthermore costs could be reduced by lowering the chance of urban floods, which is very costly for the city. The awareness about the potential and common benefits of RWH has to be increased among middle class and slum dwellers.

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Annex 1 Questionnaire

Interview outline

Code:______________ Date: ___________________ Location___________________ ______Time:______________

Roof area: _______________ Inhabitants: _____________________ Tank,etc: _____________________________

Housing type/ Roof material/Drainage____

Female ☐

Male ☐

Hello my name is Lutz Barenhoff I am from Germany and I am an exchange student from the Engineering Staff College of India. I am working in the research project sustainable Hyderabad. The aim of the Project is to find strategies to improve hyderabad towards a more sustainable city with better living conditions for every one. We making a survey in this neighborhood to identify certain problems and devices so that we can jointly with local actors in Hyderabad develop solution strategies.

Do you have 20 minutes time for a short interview?

What are the mayor problems of this neighborhood?

If Water no -->
Are you satisfied with the water supply situation?____

If Water yes--> Which are the water related problems____

Where do you get your water from?____

Which water do you drink____

Do you treat it? How____

How long do you spend getting water per day?____

How much money do you spend every month for Water?____

Did you do by yourself or in your neighborhood anything to enhance the water supply situation, how is the community organised when it comes to solve problems in the neighborhood ?

____

IF Yes what?____

____

If No Would you be willing to invest money and work to better the water supply situation, how much?____________

____

If no why not____

Do You use Rainwater?____

IF Yes how?____

For what purposes do you use the water?_____________________________________

____

If No Why?____

____

Do You know anybody in Your neighborhood Who uses Rainwater?_____________________________

Have You ever heard about Rainwater harvesting?____

Can you explain it?____

Do you own the house? ____

Do you use a water tank, how much capacity____

Which water do you put in these tanks?____

Is there enough space for a (Bigger) water tank in your house?_______________________________

Have heavy rains ever done some damage to your house or your property? If Yes what kind of damage? Does the water enter the house?

____

How often does it happen per year?____

How many people live in your house?

House Information:

Size, Roof, Tank, drip molding,

Annex 2 Survey results

Code	Date	Location	Category	Respondents Sex	Roof Area m²	Inhabitants	Roof material	Housing type	Owned / Rented	Major problems in neighborhood	Satisfied with water supply?	Water related problems?	Water sources?	Tab water distribution	Water amount tab	Alternative sources, when shortages occur?
1	08.09.10	Rasoolpura	slum	F	40	5	iron sheet	Solid 1 floor	owned	Roads/Drainage	yes	Summer water quantity	Public stand post, priv. borwe well	every second day	5-6 bh	bore well neighborhood
2	08.09.10	Rasoolpura	slum	F	25	5	asbestos	Solid 1 floor	owned	Nala flushing street bridge broke	yes	no problems	Public stand post, priv. borwe well	every second day	5-7 bh	NA
3	08.09.10	Rasoolpura	slum	F	25	10	iron sheet	not solid	owned	Roads, Floodings	yes	Summer water quantity	Public stand post, priv. borwe well	every second day	NA	Go to water tank
4	08.09.10	Rasoolpura	middle class	F	40	6	concrete	Solid 2 floor	owned	Roads/Drainage	yes	no problems	Private tab	every second day	4-5 bh	no shortage
5	08.09.10	Rasoolpura	middle class	F	50	4	concrete	Solid 2 floor	owned	Roads/Drainage	yes	Monsun water quality	Private tab community borewell	every second day	NA	no shortage
6	08.09.10	Rasoolpura	middle class	F	25	3	concrete	Solid 1 floor	owned	low water pressure	no	Qauntity problems	Private tab	every second day	NA	Go to water tank
7	08.09.10	Rasoolpura	middle class	F	50	4	concrete	Solid 1 floor	owned	Drainage	no	Monsun water quality	Private tab	every second day	150l	call tanker
8	08.09.10	Rasoolpura	middle class	F	80	15	concrete	Solid 2 floor	owned	Electricity	no	Monsun water quality, no borewell	Private tab	every second day	10 bh	bore well neighborhood
9	08.09.10	Rasoolpura	slum	M	25	5	iron sheet	Solid 1 floor	owned	Drainage	no	Quantiy	Public stand post,	every second / third day	5-6 bh	NA
10	08.09.10	Rasoolpura	middle class	F	70	5	concrete	Solid 1 floor	owned	no problems	yes	Monsun water quality	Private tab community borewell	every second day	5-6 bh	no shortage
11	09.09.10	Rasoolpura	slum	M	30	4	iron sheet	not solid	rented	Water	no	Quantity always	Public stand post, priv. borwe well	every week	2 Drums	Tab other neighborhood
12	09.09.10	Rasoolpura	slum	F	40	4	iron sheet	not solid	rented	Roads, Floodings,	no	Walking 3 km to get borewellwater	Water tanker	every 5 days	2 Drums	bore well neighborhood
13	09.09.10	Rasoolpura	slum	F	30	8	iron sheet	not solid	owned	Quantity, no power connections	no	Quantity, Monsun quality	Public stand post, priv. borwe well	every second / third day	10 bh	NA
14	09.09.10	Rasoolpura	slum	F	30	6	iron sheet	not solid	rented	High rent floodings	no	Floodings	Public stand post, priv. borwe well	every second / third day	4-5 bh	NA
15	09.09.10	Rasoolpura	slum	M	40	4	concrete	Solid 1 floor	owned	Summer Quantity	no	summer quantity, monsun quality	Public stand post, priv. borwe well	every second / third day	NA	Tab other neighborhood
16	09.09.10	Rasoolpura	slum	F	25	3	iron sheet	Solid 1 floor	rented	Drainage, Summer Quantity	no	Summer water quantity	Private shared tab	every second / third day	NA	Tab other neighborhood
17	09.09.10	Rasoolpura	slum	M	50	6	iron sheet	Solid 1 floor	owned	not enough money	no	summer quantity, monsun quality	Private tab	every second day	NA	Tab other neighborhood
18	09.09.10	Rasoolpura	slum	F	35	5	iron sheet	not solid	owned	not enough drinking water	no	Tankers do not come in this area borewell sometimes dry in summer	Shared borewell, private tab from neighbour	every second / third day	NA	NA
19	09.09.10	Rasoolpura	slum	F	60	8	concrete	Solid 1 floor	owned	mosquitos, healthcare	no	not enough water, no tab connection	Tanker	every week	2-3 drums	Tab other neighborhood
20	09.09.10	Rasoolpura	slum	F	40	2	concrete	Solid 1 floor	owned	polititians don´t care, health-	no	summer quantity, monsun quality	Tanker	every week	1-2 drums	Tab from mc area

										care, rats, roads						
21	09.09.10	Rasoolpura	middle class	M	100	16	concrete	Solid 3 floor	rented	Politcal corruption, Roads	yes	Summer water quantity	Private tab	every second day	5-6 bh	Water tanker
22	09.09.10	Rasoolpura	middle class	F	80	6	tile	Solid 1 floor	owned	no problems	yes	no problems	Private tab, shared borewell	every second day	5-6 bh	bore well neighborhood
23	13.09.10	Banjarah hills	slum	F	15	2	iron sheet	Solid 1 floor	rented	Money, Roads, Mosquitos,	yes	no problems	Private tab	every second day	2/3 bh	NA
24	13.09.10	Banjarah hills	slum	F	40	6	iron sheet	Solid 1 floor	rented	no tab connection	no	no tab connection	Public stand post, private bore well	every second day	8-10 bh	bore well neighborhood
25	13.09.10	Banjarah hills	middle class	F	100	8	concrete	Solid 1 floor	owned	no problems	no	low pressure, monsun quality	Private tab other house	every second day	6-8 bh	bore well neighborhood
26	13.09.10	Banjarah hills	middle class	F	60	5	concrete	Solid 1 floor	owned	children health, dirty water-> fevers	no	Monsun water quality	Private tab	every second day	NA	NA
27	13.09.10	Banjarah hills	middle class	F	80	7	concrete	Solid 2 floor	rented	rents to high,	no	Monsun water quality, summer quantity	Private tab	every second day	NA	bore well neighborhood
28	13.09.10	Banjarah hills	middle class	F	100	9	concrete	Solid 2 floor	owned	no problems	yes	no problems	Pivate tab	evey second day	5-6 bh	public stand post
29	13.09.10	Banjarah hills	middle class	M	80	6	asbestos	Solid 1 floor	owned	no problems	yes	no problems	Pivate tab	evey second day	NA	bore well neighborhood
30	13.09.10	Banjarah hills	middle class	M	100	7	concrete	Solid 3 floor	owned	Roads	yes	no problems	private tab	every second day	6-8 bh	NA
31	13.09.10	Banjarah hills	slum	F	45	10	iron sheet	Solid 1 floor	rented	Water Quantity	no	water qauntity, only 15 minutes running water	Private tab, shared borewell	every second day	10 bh	bore well neighborhood
32	13.09.10	Banjarah hills	middle class	M	150	4	concrete	Solid 1 floor	owned	no problems	yes	no problems	Pivate tab	every second day	10 -15 bh	NA
33	15.09.10	Indranganar colony	middle class	M	45	12	concrete	Solid 3 floor	owned	floodings	yes	Floodings	Private tab	every second day	Na	call tanker
34	15.09.10	Indranganar colony	middle class	F	50	15	concrete	Solid 3 floor	owned	no problems	yes	no problems	Private tab	every second day	6-8 bh	NA
35	15.09.10	Indranganar colony	slum	M	60	8	iron sheet	Solid 1 floor	owned	Drainage	no	only two hours per week tabed water	private tab private borewell	2 hours per week	NA	bore well neighborhood
36	15.09.10	Indranganar colony	slum	F	40	5	iron sheet	Solid 1 floor	owned	Roads, Floodings, water quality	no	water quality	Pivate tab	every second / third day	NA	call tanker
37	15.09.10	Indranganar colony	slum	F	20	1	asbestos	Solid 1 floor	rented	Floodings, rent to high	yes	no problems	Pivate tab	every second day	4-5 bh	no shortage
38	15.09.10	Indranganar colony	slum	F	100	9	concrete	Solid 1 floor	owned	water related health problems	no	water quality	Pivate tab	every second day	25 bh	bore well neighborhood
39	15.09.10	Indranganar colony	middle class	F	30	3	concrete	Solid 1 floor	rented	Drainage	no	quantity	Private tab	every second day	4-5 bh	public stand post
40	15.09.10	Indranganar colony	middle class	M	30	3	concrete	Solid 1 floor	rented	rents to high	yes	no problems	Private tab	every second day	4-5 bh	no shortage
41	15.09.10	Indranganar colony	middle class	F	40	4	concrete	Solid 1 floor	rented	Roads	no	water quality	Private tab	every second day	NA	public stand post
42	15.09.10	Indranganar colony	middle class	M	80	16	concrete	Solid 3 floor	rented	Roads, Drainage	yes	no problems	Private tab	every second day	10 bh	no shortage
43	16.09.10	Guru Shankar Nagar Colony	slum	M	60	7	iron sheet	Solid 1 floor	owned	Drainage, water quality, nala gets flooded	no	water quality	Private tab	every second day	6-8 bh	public stand post
44	16.09.10	Guru Shankar Nagar Colony	slum	F	100	20	concrete	Solid 3 floor	rented	Water Quantity	no	water quantity, coming in the middle of the night	Private tab	every second day	NA	NA
45	16.09.10	Guru Shan-	slum	F	100	25	concrete	Solid 3	rented	Water Quantity	no	water quantity,	Private tab	every se-	NA	call tanker

		kar Nagar Colony						floor		Nala smells		coming in the middle of the night		cond day		
46	16.09.10	Guru Shankar Nagar Colony	middle class	F	40	3	concrete	Solid 1 floor	rented	no problems	yes	no problems	Private tab	every second day	6-8 bh	call tanker
47	16.09.10	Guru Shankar Nagar Colony	middle class	F	50	15	concrete	Solid 3 floor	owned	Nala smells, mosquitos	yes	no problems	Private tab	every second day	NA	call tanker
48	16.09.10	Guru Shankar Nagar Colony	middle class	F	40	3	concrete	Solid 1 floor	owned	no problems	yes	no problems	Private tab	every second day	6-8 bh	NA
49	16.09.10	Guru Shankar Nagar Colony	slum	M	20	3	plastic bags	not solid	rented	no tab connection, rent to high	no	water quantity, coming in the middle of the night	Tab nighbour	every second day	4-5 bh	NA
50	16.09.10	Guru Shankar Nagar Colony	slum	F	50	7	iron sheet	Solid 1 floor	owned	no problems	yes	water quality	Private tab	every second day	6-8 bh	bore well neighborhood
51	17.09.10	Syed Nagar	middle class	F	70	11	concrete	Solid 1 floor	owned	Drainage, water quality,	no	water quality, floodings	Private tab	every second day	NA	bore well neighborhood
52	17.09.10	Syed Nagar	middle class	F	40	5	asbestos	Solid 1 floor	owned	water quality	no	water quality	Private tab	every second day	4-5 bh	bore well neighborhood
53	17.09.10	Syed Nagar	middle class	M	50	8	concrete	Solid 2 floor	owned	Roads	no	Summer water quantity	Pivate tab	every second day	NA	call tanker
54	17.09.10	Syed Nagar	slum	M	70	12	iron sheet	Solid 1 floor	owned	Drainage, water quality	no	water quantity/ water quality	Private tab	every second day	10 bh	call tanker
55	17.09.10	Syed Nagar	slum	F	40	10	asbestos	Solid 1 floor	rented	water quality, health problems	no	water quantity/ water quality	Private tab	every second day	5 bh	bore well neighborhood
56	17.09.10	Syed Nagar	slum	M	60	15	concrete	Solid 2 floor	rented	no problems	no	water quatity	Private tab	every second day	10 bh	call tanker
57	17.09.10	Syed Nagar	middle class	M	80	7	concrete	Solid 1 floor	rented	no problems	yes	no problems	Private tab	every second day	10 bh	private bore well
58	17.09.10	Syed Nagar	middle class	M	60	5	concrete	Solid 1 floor	rented	power cuts	yes	no problems	Private tab / Private bore well	every second day	NA	private bore well
59	17.09.10	Syed Nagar	middle class	F	100	10	concrete	Solid 1 floor	owned	no problems	yes	no problems	Private tab	every second day	NA	bore well neighborhood
60	17.09.10	Syed Nagar	slum	F	50	9	iron sheet	Solid 1 floor	owned	Drainage, water quality	yes	water quality	Private tab	every second day	6-8 bh	bore well neighborhood
61	17.09.10	Syed Nagar	middle class	M	60	8	concrete	Solid 2 floor	owned	no problems	yes	no problems	Private tab	every second day	10 bh	no shortage
62	22.09.10	Hakimpet	slum	M	20	5	asbestos	not solid	owned	drainage, nala smells, mosquitos	no	water quantity	Private tab	every second/third day	6 bh	public bore well
63	22.09.10	Hakimpet	slum	F	40	4	asbestos	Solid 1 floor	owned	low water pressure	no	water quatity	Private tab	every third day	10 bh	call tanker
64	22.09.10	Hakimpet	slum	M	30	4	asbestos	not solid	owned	illegal housing, fear of landslide	no	floodings, quantity, not enough work	Private tab	every third day	10 bh	no alternative
65	22.09.10	Hakimpet	slum	M	30	5	iron sheet	Solid 1 floor	owned	no water connection, no sewar connection	no	quality, quantity	public tab	every second day	20 bh	no alternative
66	22.09.10	Hakimpet	slum	M	40	5	asbestos	Solid 1 floor	owned	drainage, floodings	yes	no problems	Private tab	every second day	2-3 drums	call tanker
67	22.09.10	Hakimpet	middle class	F	32	6	concrete	Solid 1 floor	owned	roads, floodings,	yes	no problems	Private tab	every second day	10 bh	no alternative
68	22.09.10	Hakimpet	slum	F	40	4	asbestos	Solid 1 floor	owned	Drainage	yes	no problems	Private tab	every second day	NA	public bore well

69	22.09.10	Hakimpet	slum	F	50	7	iron sheet	not solid	owned	money, no proper house, health problems	no	water quantity, water quality	shared tab	every second day	6-8 bh	bublic bore well
70	22.09.10	Hakimpet	slum	F	40	5	iron sheet	not solid	owned	money problems, roads, no tab connection	no	no tab connection, heavy work to carry the water	Public stand post, private bore well	every second day	6 bh	no alternatives
71	24.09.10	Boudangar Colony	middle class	M	80	15	concrete	Solid 2 floor	owned	no problems	yes	no problems	Private tab	every second day	NA	public bore well
72	24.09.10	Boudangar Colony	middle class	F	120	14	concrete	Solid 1 floor	rented	no problems	no	water quantity	Private tab	every second day	6-7 bh	call tanker, neighbours
73	24.09.10	Boudangar Colony	middle class	F	40	5	concrete	Solid 1 floor	owned	Roads, power cuts, floodings	no	water quality	Private tab	every second day	NA	no alternative
74	24.09.10	Boudangar Colony	middle class	F	30	5	concrete	Solid 1 floor	owned	Drainage	no	Water quality	Private tab	every second day	6-8 bh	public bore well
75	24.09.10	Boudangar Colony	middle class	M	40	4	concrete	Solid 1 floor	owned	Drainage, water quantity	no	water quantity	Private tab	every second day	2 drums	private bore well
76	24.09.10	Boudangar Colony	middle class	F	100	20	concrete	Solid 3 floor	owned	no problems	no	water quantity	Private tab	ecery second day	NA	NA
77	24.09.10	Boudangar Colony	middle class	M	120	10	concrete	Solid 1 floor	owned	no problems	no	Water quality / water quantity	Private tab	every second day	10-12 bh	NA
78	24.09.10	Boudangar Colony	middle class	F	50	6	concrete	Solid 1 floor	owned	drainage, roads, mosquitos	no	water quantity	Private tab	every second day	20-25 bh	call tanker
79	24.09.10	Boudangar Colony	slum	M	30	6	asbestos	not solid	owned	nala overflow, road drainage,	yes	Water quality	Private tab	every second day	12-15 bh	no alternative
80	24.09.10	Boudangar Colony	slum	F	40	5	asbestos	not solid	rented	nala overflow, road drainage,	no	Water quality	Private tab	every second day	NA	NA

Drinking water?	Treatment of drinking water?	Monthly costs for water?	Use of rain water?	If no why not?	Method of RWH	Purpose RWH	RWH in the neighborhood?	Ever heard about RWH?	Storage?	Space fpr bigger tank?	Water entering the house?	Damage?
tab	no	15 rs bw	no	no need			no	no	2 drums	yes	no	no
tab	no	40 rs for bw	no	no need			no	no	2 drums	yes	no	no
tab	no	no	no	no need			no	no	1 drum	no	yes	rice, furniture
tab	filter ghanga	dont know	no	no need			no	no	3 drums	yes	no	no
tab	no	700 per year	no	no need			no	no	1000l Tank	yes	no	no
tab	no	130 rs	no	no strukture, roof dirty			some	no	3 drums	yes	no	no
tab	no	no	yes		bucket under roof	wasching, toilet	some	no	3 drums	yes	no	no
tab	boiling always	no	no	no need			no	no	2 drums	no	no	no
tab	no	no	no	dont know			some	yes	1 drum	no	yes	no
tab	boiling when dirty	no	no	no need			no	no	2 drums	yes	no	no
tab	no	20 rs tab, 20rs bw	yes		bucket under roof	wasching, cleaning	everybody	yes	3 drums	yes	yes	no
tanker	clothing filter when dirty	no	yes		storing in drum under roof	washing, toilet	no	no	2 drums	yes	yes	coocking material
tab	no	20 rs bw	yes		bucket under roof	wasching, toilet	yes	no	2 drums	yes	no	no
tab	no	20 rs bw	yes		bucket under roof	wasching, toilet	yes	no	2 drums	yes	yes	rice,
tab	no	20 rs tab,	summer		bhindi outside	wasching, toilet	yes	no	1 drum	yes	no	no
tab	no	half rs per bhindi	no	dont know			no	no	1 drum	no	nowerdays no	no
tab	boiling when dirty	30 rs	no	don´t know			no	no	3 drums	yes	no	no
tab	no	1 rs per bh in summer 3-4rs	yes		bucket under roof	every thing except drinking	yes	no	1 drum	no	sometimes	rice,furiniture
tanker	no	20 rs	yes		bucket under roof	wasching, toilet	yes	no	1000l Tank	yes	no	no
tanker	no	25 rs	yes		water goes di-rekt bathroom	toilet	yes	no	2 drums	yes	no	no
tab	boiling when dirty	don´t know	no	no need			no	no	3 drums	yes	nowerdays nono	
tab	no	10-20 rs bw	no	no need			no	no	2 drums	yes	no	no
tab	no	don´t know	no	dont know			no	no	1 drum	no	no	no
tab	no	200 rs for borwell	no	Na			some	no	1 drum	no	yes	dirty
tab	bleaching powder when dirty	1rs per 2 bh	yes		bucket under roof	washing, toilet	some	yes	Sump 600 l	no	no	
tab	no	70 rs	no	no needq			no	no	1 drum	no	no	no
tab	no	don´t know	no	no need			no	no	3 drums	yes	no	no
tab	no	130 rs	yes		bucket under roof	wasching, cleaning	yes	no	1 drum	yes	no	no
tab	no	150 – 200	no	no need			no	no	3 drums	yes	no	no
mineral water	no	30 rs per gallon	no	dirty			no	no	1000l Tank	yes	no	no
tab	no	don´t know	no	roof dirty			no	no	3 drums	no	no	no
tab	clorine delivered by mch	160 – 200 rs	no	noo need			no	no	5000l tank	yes	no	no
tab	when dirty steel filter	150 rs	no	no need			no	no	2 drums	yes	yes	no
tab	no	130 rs	no	no need			some	no	2 drums	yes	no	no
tab	no	50 rs	no	no need			no	no	1 drum	yes	yes	no

tab	Boilng + filtering (Ghan-ga filter)	150 rs	yes		bucket under roof	wasching, cleaning	yes	no	2 drums	no	yes	furniture
tab	no	includet in rent	yes		bucket under roof	washing, toilet	yes	no	1 drum	no	yes	furniture, coocking material
tab	no	380 rs	yes		bucket under roof	wasching, cleaning	some	no	Sump 300 l	no	no	
tab	boil	150 rs	no	no need			no	no	1 drum	no	yes	coocking material
tab	no	120 rs	no	no need			no	no	2 drums	yes	yes	furniture, no sleep
tab	boiling when dirty	140 rs	no	no need			no	no	1 drum	yes	no	
tab	filtering always	120 rs	no	no need			no	no	1 drum	yes	no	
tab	no	200 rs	no	no need			no	no	1 drum	no	no	
tab	filtering always	1000 rs	no	dont know			no	no	NA	yes	no	
tab	no	250 rs	no	no need			no	no	NA	yes	no	
tab	filtering always	includet in rent	no	no need			no	no	NA	yes	no	
tab	no	500 rs	yes		bucket under roof	washing, toilet	yes	no	3 drums	no	no	
tab	no	150 rs	yes		water goes di-rekt bathroom	washing, toilet	yes	no	2 drums	yes	no	
tab	boil	includet in rent	yes		bucket under roof	washing, toilet	yes	no	NA	no	yes	furniture, coocking material
tab	no	200 rs	no	no need			no	no	3 drums	yes	no	
tab	boil	150 rs	yes		bucket under roof	washing, toilet	no	no	2 drums	yes	no	
tab	steel filter	130 rs	yes		bucket under roof	wasching, cleaning	yes	no	1 drum	yes	no	
tab	boil	250 rs	no	no need			no	no	1000l Tank	yes	yes	
tab	no	300rs	yes		bucket under roof	washing, toilet	yes	no	2 drums	yes	yes	furniture
tab	boil	150 rs	no	surface is dirty			no	no	2 drums	no	no	
tab	boil	300rs	yes		buckets under roof	toilet	yes	no	1 drum	yes	no	
tab	boil	150 rs	yes		bucket under roof	toilet	no	no	1000l Tank	yes	no	
tab	no	dont know	no	no proper building			no	no	3 drums	no	no	
tab	no	200 rs	no	no need, dirty			no	no	3 drums	yes	no	
tab	no	140 rs	yes		bucket under roof	toilet, washing	yes	no	2 drums	yes	no	
tab	no	250 rs	no	no need			yes	no	4 drums	yes	no	
tab	no	90 rs	no	dont know			no	no	2 drums	no	no	
tab	no	illegal connection	yes		buckets under roof	washing, cleaning	yes	no	1 drum	yes	no	
tab	no	no	yes		bucket under roof	washing	yes	no	2 drums	yes	no	
tab	no	no	yes		bucket under roof	washing, cleaning	yes	no	1 drum	yes	yes	furniture cooking material
tab	bleaching powder when dirty	120 rs	no	no need			no	no	3 drums	yes	yes	no damage
tab	no	200 rs	yes		bucket under roof	washing, toilet	yes	no	3 drums	no	no	
tab	clothing filter when dirty	no	no	no need			no	no	2 drums	no	no	
tab	no	150 rs	yes		bucket under roof	cleaning, washing	yes	no	2 drums	no	yes	cooking material
tab	boil	100 rs	yes		buckets under	cleaning, washing	yes	no	1 drum	no	no	

					roof							
tab	aqua fine filter	170 rs	no	no need			no	no	2 drums	yes	no	
tab	boil	370 rs	yes		buckets under roof	washing, toilet	yes	no	3 drums	yes	no	
tab	boil	120 rs	no	no need			no	no	2 drums	yes	no	
tab	filtering	na	yes		buckets under roof	washing,	yes	no	2 drums	yes	no	
tab	filtering aqua guard	120 rs	no	roof is dirty			no	no	1000l Tank	no	no	
tab	no	120 rs	no	no need			no	no	2 drums	no	no	
tab	filtering	130 rs	yes		buckets under roof	washing, toilet	no	no	2 drums	yes	no	
tab	filtering	150 rs	no	surface dirty			no	no	2 drums	yes	no	
tab	boil	100 rs	no	no need			no	no	3 drums	yes	no	
tab	no	140 rs	no	dirty			no	no	2 drums	yes	yes	furniture cooking material