To centralize or not to centralize:
Planning appropriate sanitation infrastructure in Leh Town, Ladakh, India

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ABSTRACT: Safe drinking water access is already a very serious issue for large populations in fast-growing economies such as India, which is being exacerbated by climate change. Leh Town, the capital of Ladakh, India is at the centre of a fast expanding and globalising tourism-based economy. Located in an ecologically vulnerable semi-arid region of the Himalayas, Leh has expanded exponentially in the past decades. Significant lifestyle changes for the local population are augmenting already very serious environmental issues caused by lack of water and sanitation infrastructure, and consumption patterns of limited water resources. Thus, an integrated urban planning strategy linking wastewater management and water resources conservation is a pressing task. Field survey was conducted between July 2012 and February 2013, including Geographic Information Systems (GIS) mapping of guesthouses, hotels and point sources of water pollution, and a questionnaire survey of 200 households and 70 hotels and guesthouses. It is found that guesthouses and hotels have increased predominantly on agricultural land and point sources of water pollution tend to cluster in rapidly transforming parts of Leh, potentially impacting groundwater quality. This study advocates a decentralized sanitation system for groundwater resources conservation in Leh.

Keywords: Urban water resources management, health, India.

INTRODUCTION
Rapid urbanization in developing economies such as India is inducing water-related environmental challenges [1] as urban infrastructure planning is often unable to keep up with the pace of development. The resulting lack of access to safe water and sanitation is increasing water-related health risks [2], which are further being exacerbated by climate change induced water scarcity [3]. Especially in regions where water is already scarce, integrated urban planning taking health issues into consideration is needed.

Health issues do not directly drive urban design, but they did provide the original impetus for the urban planning profession: the discovery in 19th century London that cholera is a water-borne disease, for example, and that it was spreading from one particular contaminated water pump had huge implications. Thus, urban design is considered a powerful tool for addressing public health concerns [4,5] and new frameworks linking public health and urban planning are needed [6] in order to address contemporary challenges. Studies on the relation between the built environment and health are often confined to certain academic fields and their theoretical frameworks and terminologies, taking results difficult to share [7]. Further, most such studies focus on developed country contexts rather than developing countries like India. Hence increase in cross-disciplinary collaboration to strengthen the associations research cooperation [9] enabling cross-country learning experiences are needed.

Although one of the earliest examples of public sewerage was found in the ancient Indus Valley, India today is facing a sanitation crisis in part due to colonial heritage [10]: only 16 percent of the urban population have access to adequate sanitation resulting in large scale open defecation and thus ground and surface water pollution [11]. Water and health studies tend to focus on large cities while there is a dearth of information about small and medium-sized cities. Historically, although industrializing Europe sewerage or centralized sanitation systems proved very effective in curbing the spread of disease related to water and poor sanitation in urban areas, they are very water-intensive to operate: thus, industrializing Europe sewerage or centralized sanitation systems are increasingly being recognized as a way to help protect and conserve water resources [12]. Alternatives include various types of decentralized sanitation systems such as Ecosan [13]. Although these alternative systems have various advantages such as water conservation, nutrient recovery, low maintenance cost, etc. [14], they have relatively rarely been implemented successfully. Instead, the flush toilet and centralized sanitation / sewage system, which has been termed “ecologically mindless”, remains a preferable option [15] as a symbol of “modernity”. Whilst decentralization in the water sector in India has helped...
of issues surrounding health in urban India, new approaches are needed [17].

A small town in a water-scarce region is taken as a case study. Leh Town, the capital of Ladakh Region of Jammu & Kashmir State, is considered one of the fastest-expanding small towns in India [18]. Located in a remote ecologically sensitive semi-arid region in the Himalayas at an altitude of 3,500 metres above sea level, Leh is a green oasis of agricultural fields between barren mountains and fringing a historic town centre (Figure 1). The Ladakh Autonomous Hill Development Council (LAHDC) has been governing Leh since 1995. According to the 2011 Census, Leh Town has a population of 17,553. In addition, there are 40,000 army personnel [19] and several thousand migrant workers come to Leh every summer.

Ground- and spring water are the main water resources of Leh as rainwater is negligible and glacial melt water is decreasing [20] possibly due to climate change, and is only sufficient for irrigation. The green oasis of Leh is not a natural occurrence, but the result of hundreds of years of careful management of limited water resources and cultivation of a fertile desert. Since 1974 when Ladakh was opened to tourism, the number of visitors has increased exponentially, and in 2012, 79,000 tourists visited Leh. Most tourists visit between April and October, but in the harsh winters only the local population remains.

To cater to the huge increase in visitors, hundreds of guesthouses and hotels have been constructed in Leh. Ladakhi dry toilets are an example of a traditional decentralized sanitation system with nutrient recovery for agriculture and do not require any water. However, with changing lifestyles and the majority of tourists referring to use flush toilets [21], water demand has increased.

Public Health Engineering Department (PHE) supplies about 80 percent of Leh Town’s water demand through groundwater extraction in the summer months [22], but this only suffices to provide running water for a few hours per day, which is insufficient for the operation of flush toilets and showers. Thus, guesthouses and hotels are increasingly constructing private bore wells to procure additional water. Environmental pollution through lack of adequate sanitation and rubbish dumping is already severe and it is thus assumed that groundwater pollution due to seepage is occurring. Increase in water-borne diseases such as hepatitis an diarrhoea were already recorded in Leh over a decade ago [23] and incidences of diarrhoea have risen since which is not expected with economic growth and may be linked to groundwater pollution [24].

The aim of this study is to characterize the water management situation and to highlight opportunities and challenges for implementing a decentralized sanitation system in Leh.

**METHODOLOGY**

Field survey was conducted between July 2012 and February 2013 in collaboration with the Ladakh Ecological Development Group (LEDeG), a local non-governmental organization. Global positioning system (GPS) was used to map new hotels, guesthouses and restaurants, and 270 point sources of water pollution. A WorldView-2 very high-resolution satellite image (ground resolution 50 cm) from November 2011 served as a base map. Geographic information systems (GIS) data on rivers, roads, hotels and guesthouses mapped by Akhtar [21] were used. Further, questionnaire survey of 200 households and 70 hotels and guesthouses was conducted, as well as semi-structured interviews with a range of stakeholders.

**RESULTS**

There has been a dramatic increase in the number of hotels and guesthouses in Leh Town in the past decade: in the 1980’s there were only 24 hotels and guesthouses in Leh, but by 1990 there were 62, by 2000 there were 117, by 2010 there were 282, and just from 2010 to 2012, the number had increased to ca. 360 guesthouses and hotels in business, with another ca. 60 not yet in business or under construction (Figure 2). Of 21 wards in Leh Town, 10 have agricultural land, whilst the other 11 are predominantly desert-like. The study found that 9 percent of hotels and guesthouses in Leh are located in wards with agricultural land area (Figure 2).
The huge increase in tourists in Leh signifies a huge increase in water demand. Hotels and guesthouses strive to provide flush toilets and showers to increase their rating and, thus, their overnight prices, according to the interview surveys. Thus, on top of the official extraction of groundwater by PHE, the questionnaire survey revealed that 52 percent of hotels and guesthouses have private bore wells, and are each extracting several thousand litres daily from the groundwater in the tourist season. For example, one hotel owner interviewed of a hotel with 18 en-suite rooms reported extracting up to 8,000 litres per day during the tourist season.

Focusing on water pollution factors in the 10 wards of Leh Town with predominantly agricultural land, the study found that as there is currently no overall or systematic wastewater management existing in Leh, otels and guesthouses use septic tanks or soak pits to collect black- and grey wastewater. Many guesthouses were found to have only soak pits, potentially representing a significant source of effluents and thus roundwater pollution threat. In addition, 270 point sources of water pollution were mapped in the wards with predominantly agricultural land, which can be divided into three categories (total numbers of each are in brackets):

1. Black water pollution sites including black water inlets (from toilets) (8), public toilets without septic tanks and foul-smelling empty
2. Grey water pollution sites including grey water inlets (other bathroom and kitchen wastewater) (216), clothes (12) and car washing points (1);

Of all point sources of water pollution, 80 percent are grey water inlets, which is of concern because with grey water increasing amounts of chemicals are being released into the water system in Leh from detergents used for cleaning and washing purposes. Further, 4 restaurants were mapped in wards with predominantly agricultural land (Table 1). The field survey revealed that many restaurants in the agricultural land wards of Leh Town are garden restaurants without sanitary infrastructure and only dug pit toilets, so that effluent from restaurants along rivers and streams signify both surface and groundwater pollution threat.

The wards with predominantly agricultural land in Leh Town can be divided into 5 inner and 5 outer wards being those directly adjoining the ancient town centre. 96 percent of hotels, guesthouses and restaurants are located in the inner wards. Consideration of the distribution of point sources of water pollution in terms of proximity to rivers and streams in these 1 wards showed the following: hardly any point sources of water pollution were found in the outer wards. The percentage of the total number of point sources of water pollution located within 100 metres of a river or stream was more than twice as high in the inner than in the outer ward where point sources of water pollution were found. Further, the relation of the number of hotels, guesthouses and restaurants to the percentage of point sources of water pollution within 100 metres of a river or stream was clearly the highest in the two wards Tukcha and Karzoo, which have the largest number of hotels, guesthouses and restaurants. Thus, increase in water pollution may be directly linked to the tourism industry. Overall, 62 percent of point sources of water pollution in the wards with predominantly agricultural land in Leh Town are within 100 metres of rivers and streams (Table 1).

<table>
<thead>
<tr>
<th>Ward ID</th>
<th>Ward Name</th>
<th>Ward Type</th>
<th>No. of Hotels/GH (G)</th>
<th>No. of Restaurants (R)</th>
<th>No. of Pollution Points (PP)</th>
<th>No. of PP within 100 Metres of a River/Stream</th>
<th>% of total No. of PP within 100 Metres of a River/Stream</th>
<th>Relation of No. of PP within 100 Metres of a River/Stream to Total PP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sankar</td>
<td>Inner</td>
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<td>0</td>
<td>24</td>
<td>10</td>
<td>73%</td>
<td>1</td>
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<tr>
<td>2</td>
<td>Shyamur 2</td>
<td>Inner</td>
<td>17</td>
<td>4</td>
<td>55</td>
<td>24</td>
<td>44%</td>
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<td>3</td>
<td>Shyamur 3</td>
<td>Inner</td>
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<td>55</td>
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<td>44%</td>
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<tr>
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<td>Tukcha</td>
<td>Inner</td>
<td>103</td>
<td>18</td>
<td>97</td>
<td>66</td>
<td>68%</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Karzoo</td>
<td>Inner</td>
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<td>17</td>
<td>36</td>
<td>24</td>
<td>67%</td>
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<td>6</td>
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terms of the local populations perception of water issues, the questionnaire survey revealed that although 8 percent of households thought that drinking water quality is safe in Leh, 49 percent of households thought rinking water quality today is worse than 10 years ago. 5 percent of households reported having problems with their drinking water in terms of smell, taste or colour. Lack of adequate sanitation system, i.e. septic tanks, or soak pits, were thought by 31 percent of households to be the main source for groundwater pollution. Increased use of chemical fertilizer in agriculture was also received as a water quality threat. 40 percent of households thought drinking water pollution is related to diarrhoea. Thus, this study finds drinking water pollution to be a serious concern of the local population.

**DISCUSSION**

Groundwater extraction is not regulated in Leh, and the total number of bore wells, rates of extraction and roundwater aquifer levels are currently not known. An increasing percentage of hotels and guesthouses are installing showers and flush toilets although, according to the interview survey, inhabitants think that some springs in Leh seem to have dried up because of high rates of groundwater extraction. There is so far no strategy tackling water issues in Leh from the demand side. Negligible rainfall, decrease in surface water and in irrigated agricultural land due to hotel and guesthouse construction, added to the sum of PHE and private extraction by hotels and guesthouses, may mean that roundwater is being depleted faster than the rate of recharge in Leh. Further spatial investigation of distribution of water resources and water demand may help to estimate Leh’s carrying capacity in terms of water resources, which currently is not known. Overall, the type and distribution of water pollution in Leh indicates further environmental planning is needed.

Currently, PHE supplies following daily estimates during summer months from these sources [25]:

1. 1-2 million litres extracted via four tube wells from the Indus River aquifer;
2. 1.3 million litres extracted from various tube and bore wells distributed in Leh Town;
3. 0.8 million litres channelled from various springs near the top of Leh Town.

Thus, most of Leh Town’s water demand is being provided through groundwater extraction via bore and tube wells. Water from the Indus River aquifer is being lifted several hundred meters up to reservoirs distributed in Leh Town, which is very energy intensive. From the and private water taps. An additional several thousand litres daily are distributed to the local population without access to any taps by water tankers. Various stakeholders according to the interview survey at voicing concern that groundwater resources in Leh are being over-depleted. However, the main concern of PHE, also according to the interview survey, is how to procure ever more water from groundwater and river water sources.

Although LAHDC aims to promote Ladakh as an eco-tourism destination and even an “ideal society”, an conserve and protect water resources, in practice this is difficult to implement as the environment is common degraded due to lack of awareness or for short-sight monetary gains [26]. Due to decrease in the primar farming sector as a multitude of other job opportunitic have opened up, Ladakh currently already has an impo dependency ratio of 60 percent for food [27]: thus LAHDC plans to use groundwater for irrigation in order to boost food production and to introduce legislatio completely banning construction on agricultural land [26]. Energy provision is also already a challenge in Leh, with the town facing regular daily electricity cuts.

A decentralized sanitation system in Leh may help address these challenges as well as to conserve an protect groundwater resources by enabling:

1. Conservation of water resources by using less water for flushing;
2. Nutrient recovery and continuation of traditional practices and use of natural fertilizers as opposed to chemical fertilizer in a still actively agricultural society;
3. Wastewater can be used in agriculture instead of needing to procure additional water for irrigation;
4. Less environmental pollution of soil and water resources and loss of water due to less seepage due to shorter pipes;
5. Lower energy consumption due to less water having to be lifted from groundwater resources and pumped up-hill;
6. Renewable energy production (biogas);
7. Lower costs of installation and maintenance.

In addition, wastewater could be treated and channelled back to replenish the aquifer proportionally to demand locally. Despite these advantages, to implement a decentralized sanitation system effectively will require significant increase in awareness of inhabitants and tourists to initiate change in water consumption behaviour. One hotel in Leh is currently already implementing its own decentralized wastewater
In order to deal with increasing amounts of wastewater, the LAHDC plans to implement a centralized sanitation system by 2040 through a private company which is lanced to comprise about 20 kilometres of piping to be laid at a depth of 2 metres below the surface to avoid freezing in winter and with a central water treatment plant close to the Indus River aquifer, again several undred metres below Leh Town [28]. However, such a centralized sanitation system may require increased water resources in order to flush long pipes, which will turn require more energy for extraction, and may entail high maintenance costs due to the harsh climate and rugged topography.

Despite these seemingly natural constraints to the implementation of a centralized sanitation system, nonetheless, such a system represents a large-scale infrastructure investment opportunity for the local government. Further, the centralized system may symbolize the “modernity” that a society facing the burdens of rapid transition and as recently still completely traditional as Ladakh wishes to strive for. With its apparent record of success, the centralized sanitation system still stands for “business as usual”.

However, until quite recently, this same traditional society was using only a decentralized sanitation system, i.e. Ladakhi dry toilet, which was very well adapted to the local conditions. The Ladakhi dry toilet is an elevated slab, sometimes as part of a house or as a separate out-house, where faecal matter falls into a hamber beneath the slab and is covered after each visit by a shovelful of earth – hence “dry” as no water is used. The faecal matter is stored and used as dry agricultural fertilizer by adding it to irrigation water. While many of the local population continue to utilize the Ladakhi dry toilet, also because fertilizer remains available in agriculture, the vast majority of tourists to Leh prefer to use the flush toilet because it is considered more convenient and hygienic. As a result, hotels and guesthouses strive to provide flush toilets en-suite to all rooms.

Due to administrative decentralization, ratification of the Indian Groundwater Act is still pending in Ladakh. At the same time, the increasingly autonomous government is short of funds, leaving it prey to investors keen to sell expensive infrastructure. Despite evident need for sanitation infrastructure, the government may shy away from addressing the issue in more detail as poverty linked to the caste system and sanitation most directly, continues to be a highly political and sensitive issue in India.

In-depth understanding of stakeholder decision-making and power distribution is needed to approach water-related health risks through alternative urban development scenarios effectively. There may be a range of options potentially better suited to the water scarcity situation in Leh that could even present innovative opportunities for eco-tourism. Perhaps a decentralized system can implement like a centralized one and thus also present investment opportunity, or there may be hybrid option. In any case, this study advocates a study of Leh’s carrying capacity in terms of water resources, and an independent evaluation of both a centralized and decentralized sanitation system in terms of which is more beneficial for water resources conservation. With an appropriate vision, Leh has the full potential to become an international lighthouse example of an “ideal eco-society”.

CONCLUSION

As long as short-term economic goals prevail and developing enough awareness of water issues in Leh, change water consumption patterns will be difficult. A fixed idea of “modernity” predominantly through technological solutions and a “earn money first, clean later” approach, has also not served the Western world at all well in all instances. Decentralized sanitation technology may be “old hat” per se, but implementing innovative approaches in the development as well as in the developed contexts is still a far cry from a routine process. One of the most difficult challenges we face is our time to open our mindsets to allow alternative and perhaps more appropriate visions of “modernity” into existence so that we can systematically evaluate them.

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