Running out of water - in India

Henrik Valeur, 2013

Abstract

While “the green revolution” helped prevent famine the introduction of chemical pesticides and fertilizers, water intensive crops and groundwater irrigation in India in the late 1960’s has contributed signi ficantly to the pollution and depletion of water, and to population growth, which in combination has reduced the amount of water available per person by more than 2/3, causing water stress today and possible scarcity within the next few decades. So far most of the population growth has taken place in rural areas but from now on almost all of the growth is expected to take place in urban areas. The future water situation in India will therefore increasingly be decided by the capability of its cities to conserve and recycle water.

This paper was published in Valeur, H (2014) *India: the Urban Transition – a Case Study of Development Urbanism*. Copenhagen, The Architectural Publisher B.

Content

1. Water pollution

"Water contamination weakens or destroys natural ecosystems that support human health, food production and biodiversity. Water-borne diseases kill millions people […]. Livelihoods such as agriculture, fishing and animal husbandry are affected by poor water quality".

Yet …

"Presently, only about 10 per cent of the waste water generated is treated; the rest is discharged as it is into our water bodies".[1]

Wastewater is, however not the only problem.

1.1 Mavallipura – the dumpsite

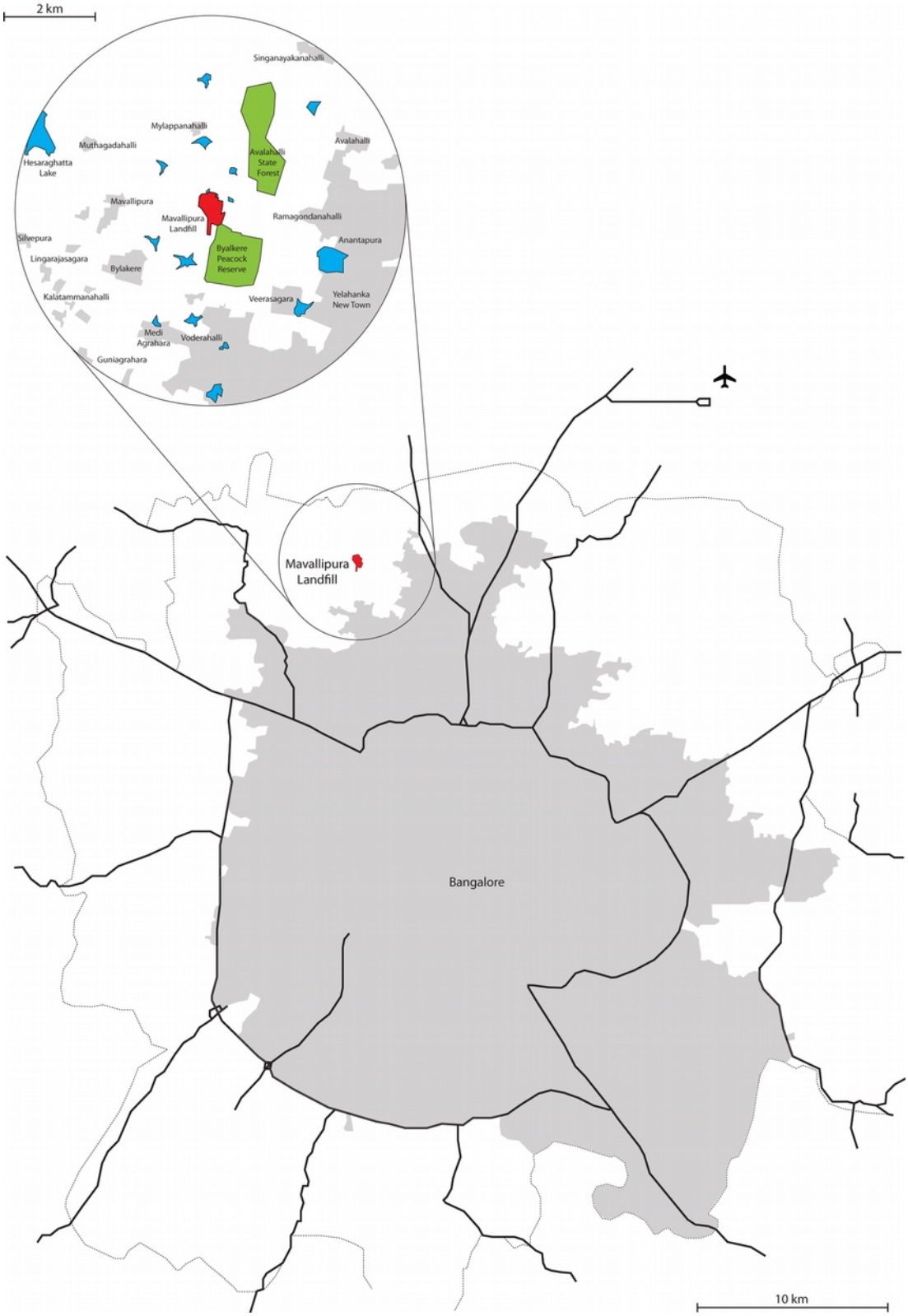
During the past decade the city of Bangalore dumped more than a million tons of solid waste at Mavallipura, a landfill located just outside the city, between the Avalahalli State Forest and the Byalkere Peacock Reserve,[2] surrounded by agricultural land, lakes and villages.

According to environmentalists and local residents, highly toxic leachate has begun leaking into the nearby lakes, streams and groundwater while the inhabitants of the surrounding villages have begun to suffer from abnormally high levels of cancer, kidney failure and gastro-intestinal disorders.[3]

1. Both quotes from: Comptroller and Auditor General of India (2012) *Performance Audit of Water Pollution in India*.

2. Apart from being a sanctuary for India's national bird and several endangered animals, the Byalkere Peacock Reserve is also said to be the only remaining grassland in Bangalore.

3. Source: Environment Support Group (2012) *KSPCB shuts down Ramky's SWM Landfill at Mavallipura*: http://www.esgindia.org/campaigns/press/kspcb-shuts-down-ramkys-swm-landfill-mav.html (and embedded links).



Map of the metropolitan area of Bangalore and the area around the Mavallipura landfill (top). Image © Henrik Valeur, 2013.

Animals are reported to have died from drinking the water while mosquitoes, and with them malaria and dengue fever, proliferate. But what finally made the State Pollution Control Board put a stop to the practice of dumping garbage at Mavallipura was maybe not so much the health of the villagers as it was the rumour that the water supply to the city itself was being contaminated and the fact that the expanding city was rapidly approaching this area, having already caught up with the nearby Yelahanka New Town - once a model satellite town located far outside the city when built in the 1970's – the population of which tripled from around one hundred to around three hundred thousand inhabitants during the last decade (2001-11).[4]

Nevertheless, mountains of untreated solid waste remain and even though it has been covered with earth, it is exposed by heavy rainfall during the monsoon.

1.2 Sources of pollution

Water safety is threatened by pollution from a variety of human activities. This includes untreated domestic waste and sewage, especially from urban households,[5] industrial effluents and toxic substances, agricultural run-off from fertilizers and pesticides.

But it is also threatened by natural contamination,[6] for instance the intrusion of saltwater from the sea contaminating the soil, surface water and groundwater aquifers.[7] Salinity also occurs in many inland areas such as the arid regions of Rajasthan and Gujarat, where *"ground water salinity is so high that the well water is directly used for salt manufacturing by solar evaporation"*.[8]

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4. Source: Wikipedia (n.d.) *Yelahanka*: http://en.wikipedia.org/wiki/Yelahanka (accessed 22.10.2013).

5. "The smaller towns and rural areas do not contribute significant amounts of sewage due to low per capita water supply." Quoted from: Central Pollution Control Board, Ministry of Environment & Forests (2007) *Evaluation Of Operation And Maintenance Of Sewage Treatment Plants In India*.

6. Natural contamination of water in India includes salinity (in Rajasthan, Kerala, Karnataka), iron (in Assam, Bihar, Chattisgarg), nitrate (in Karnataka, Rajasthan, Maharashtra), fluoride (in Rajasthan, Karnataka, Bihar) and arsenic (in Assam, West Bengal, Bihar). Source: *Contaminated water stunting growth of Indian kids: UNICEF*. Hindustan Times, 14 February 2013: http://www.hindustantimes.com/India-news/NewDelhi/Contaminated-water-stunting-growth-of-Indian-kids-UNICEF/Article1-1011753.aspx

7. Source: UNICEF, FAO and SaciWATERs (2013) *Water in India: Situation and Prospects*. The salination of soil, surface and groundwater reduces the availability of safe drinking water and arable land.

8. Quoted from: Central Ground Water Board, Ministry of Water Resources (n.d.) *Groundwater quality scenario*: http://www.cgwb.gov.in/GW_quality.html (accessed 22.10.2013).

Water pollution from agriculture can be traced back to the so-called "green revolution", launched in India in the late 1960's. The introduction of modern farming methods and technologies, chemical fertilizers and pesticides, high-yield crops and intensive irrigation helped reduce malnutrition and starvation, thus improving the changes of survival while increasing life expectancy.[9] But it also allowed the population to grow at more than 20 percent per decade during the second half of the 20th century,[10] putting further pressure on the water resources. And it led to severe land degradation, depletion of groundwater and pollution of both surface and groundwater.

Agriculture contributes 55 percent to the pollution of water in India. The rest comes from domestic use (26 percent) and industrial production (19 percent).[11]

Industrial water pollution includes chemicals, pharmaceuticals and heavy metals from factories, foundries, laboratories and tanneries. A report about industrial water pollution in India describes how the Amla Khadi, a tributary of the Narmada river in the state of Gujarat, "*carries extremely toxic, often acidic, dark brown or black effluents around the year*".[12]

In many cases, industrial wastewater is dumped directly into local rivers and streams without prior treatment.[13]

The same goes for much of the urban household sewage: *"Indian cities produce nearly 40 billion liters of sewage every day and barely 20 percent of it is treated"*.[14]

9. As late as 1951, life expectancy in India was just 32 years. Today it is 66 years. Source: Jean Dréze and Amartya Sen (2013) *An Uncertain Glory – India and Its Contradictions*.

10. From 1901 - 1951 the population of India increased about 50% from 238 million to 361 million, but from 1951 - 2001 it almost tripled to 1.027 million. In the 21st century the growth seems to slow down, possibly as an effect of increased urbanization. Source: Central Pollution Control Board, Ministry of Environment & Forests (2013) *Performance Evaluation of Sewage Treatment Plants under NRCD*. Population figures differ slightly between different sources.

11. Source: Mekonnen, M.M. and Hoekstra, A.Y. (2011) *National water footprint accounts: the green, blue and grey water footprint of production and consumption*.

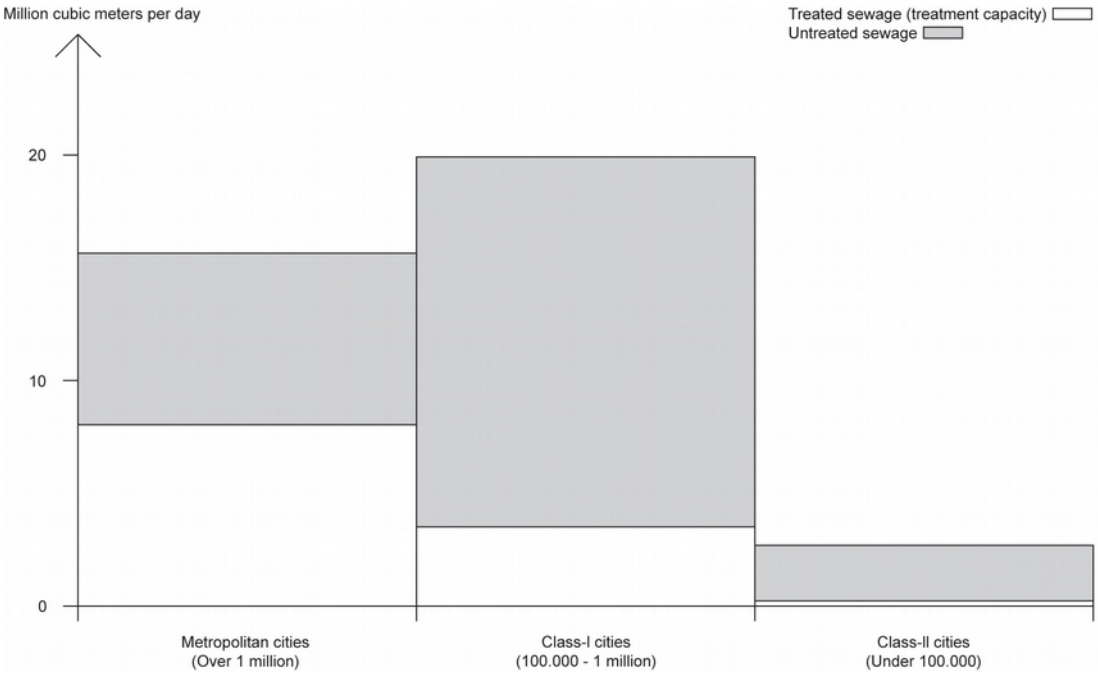
12. Quoted from: T. Rajaram and Ashutosh Das (2007) *Water pollution by industrial effluents in India: Discharge scenarios and case for participatory ecosystem specific local regulation*.

13. Source: UNICEF, FAO and SaciWATERs (2013) *Water in India: Situation and Prospects*.

14. Quoted from: Centre for Science & Environment (2013) *Excreta does matter*. Metropolitan, Class-I and Class-II cities combined produce 38.255 Ml of sewage per day equal to about 14 Gm^3 per year. If only 20% of this is actually being treated – there is capacity to treat 30% - more than 11 Gm^3 of untreated sewage is discharged from Indian cities per year. Source: Central Pollution Control Board, Ministry of Environment & Forests (2013) *Performance Evaluation of Sewage Treatment Plants under NRCD*.

Larger cities, of course, produce more sewage than smaller cities, but the average inhabitant of metropolitan and class-I cities also generate considerable more sewage than the average inhabitant of the smaller class-II cities.[15]

Larger cities, however, have relatively more treatment capacity with metropolitan cities having treatment capacity for more than 50 percent of the sewage they generate while class-I cities have capacity for less than 20 percent and class-II cities for less than 10 percent.



Total sewage generation and treatment capacity in Indian cities by size. 35 metropolitan cities generate 15,64 Mm^3 of sewage per day and their capacity of treatment is 8,04 Mm^3/day. 463 class-I cities generate 19,91 Mm^3 of sewage per day and their capacity of treatment is 3,51 Mm^3/day. 410 class-II cities generate 2,7 Mm^3 of sewage per day and their capacity of treatment is 0,23 Mm^3/day. Note that actual sewage treatment is lower than capacity "due to inadequacy of the sewage collection system", according to the Central Pollution Control Board. Source: Central Pollution Control Board, Ministry of Environment & Forests (2013) *Performance Evaluation of Sewage Treatment Plants under NRCD*. Image © Henrik Valeur, 2013.

"A large number of […] cities/towns either do not have any sewerage system or the sewerage system is overloaded or defunct. Even where sewers exist, they often leak or overflow, releasing their contents to storm water or other surface drains or

15. On average, the individual resident of a metropolitan or class-I city generates 156 l of sewage per day while the resident of a smaller class-II city "only" generates 90 l of sewage per day. There are 35 metropolitan cities with a population above 1.000.000, 463 class-I cities with a population between 100.000 and 1.000.000, and 410 class-II cities with a population between 50.000 and 100.000. Source: Central Pollution Control Board, Ministry of Environment & Forests (2013) *Performance Evaluation of Sewage Treatment Plants under NRCD*.

percolate in to soil to reach ground-water".[16]

Regular flooding due to the monsoon and extreme weather conditions further exacerbates the problem of water pollution.[17]

And even though the majority of the urban population in India has access to improved sanitation,[18] 50 million people still perform open defecation in Indian cities.[19]

Storm-water drain in Bangalore. Photo © Henrik Valeur, 2012.

16. Quoted from: Central Pollution Control Board, Ministry of Environment & Forests (2007) *Evaluation Of Operation And Maintenance Of Sewage Treatment Plants In India*.

17. Source: UNICEF, FAO and SaciWATERs (2013) *Water in India: Situation and Prospects*.

18. Improved sanitation is defined as facilities that hygienically separate human excreta from human contact.

19. Source: WHO and UNICEF (n.d.) *Joint Monitoring Programme for Water Supply and Sanitation*: http://www.wssinfo.org (accessed 22.10.2013).

1.3 The holy rivers and the fertile land

Most cities in India are located on the banks of a river and even though many rivers are sacred and water is considered the most precious resource, most of the urban waste ends up in the rivers.

Even in the national capital only about half of the residents are connected to the city's sewage system and Delhi has the largest capacity for sewage treatment of all cities in India.[20] The rest flush their wastewater directly into the Yamuna-river in which many people wash their clothes and their bodies.

The Yamuna originates in the Himalayas and flows parallel to the Ganges-river, via Delhi and past the Taj Mahal in Agra, until they meet in Allahabad,[21] where an estimated 30 million Hindu pilgrims took a bath in a single day during the Kumbh Mela in 2013.[22]

Despite having spend over 17 billion rupees on cleaning these two great - and greatly polluted - rivers, in 2009 the Government of India was quoted of saying that *"rivers Ganga and Yamuna are no cleaner now than two decades ago"*.[23]

From Allahabad the Ganges continues eastwards to the Bengal Delta where it meets the Brahmaputra-river before emptying into the Bay of Bengal. The area around the Ganges-river is known as the Ganges-basin, a historically highly productive agricultural area, which is home to more than half a billion people - the largest concentration of human beings on Earth.[24]

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20. Source: Central Pollution Control Board; Ministry of Environment & Forests (2013) *Performance Evaluation of Sewage Treatment Plants under NRCD*.

21. According to legend, the Yamuna and the Ganges merges with a third river, the mythical underground Saraswati, at Allahabad making this the holiest of any river site in India. Hindus believe that a bath here will wash away all one's sins and free one from the cycle of rebirth.

22. Source: *India's Kumbh Mela festival holds most auspicious day*. BBC, 11 February 2013: http://www.bbc.co.uk/news/world-asia-india-21395425

23. Quoted from: *Failure of Ganga, Yamuna projects no deterrence for TN govt*. Times of India, 4 September 2009: http://articles.timesofindia.indiatimes.com/2009-09-04/chennai/28093527_1_cooum-treatment-plants-sewage-treatment. It is argued that the reason for the failure was the uncritical adoption of a Western system of sewage treatment, which required 24 hours power supply when only 8 hours was available.

24. Source: Wikipedia (n.d.) *Ganges Basin*: http://en.wikipedia.org/wiki/Ganges_Basin (accessed 22.10.2013).

1.4 Health effects

Water pollution may affect food safety and security while causing degradation of eco-systems and reduction of biodiversity and, last but not least, adversely affecting human health.

Many diseases are waterborne with bacteria, viruses and parasites spreading through contaminated water and infection occurring while bathing, washing, drinking and eating. Contaminated water is said to be the main cause for the rising child mortality rate in India.[25]

Waterborne diseases include cholera, dysentery and typhoid. Malaria and dengue fever is transmitted by mosquitoes while intestinal and parasitic worms, which also proliferate and spread through contaminated water, may cause malnutrition, anemia, retarded growth and severe diseases. Natural pollutants in water, such as arsenic and fluorides, may cause skin ailments, cancer and bone diseases. Industrial pollutants, including pollutants from industrialized agriculture, may have some of the same health effects as natural pollutants in addition to possible neurological effects and alterations of the chromosomal makeup of future generations.[26]

1.5 Diarrhea

Diarrhea is among the most common waterborne diseases in India[27] with five percent of disability-adjusted life year[28] in India caused by diarrhea alone.[29]

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25. Source: *Clean water still a dream for 4.6 crore*. Times of India, 4 September 2013: http://articles.timesofindia.indiatimes.com/2013-09-04/india/41764342_1_drinking-water-habitations-contaminated-water

26. Source: UNICEF (n.d.) *Common water and sanitation-related diseases*: http://www.unicef.org/wash/index_wes_related.html (accessed 28.10.2013).

27. ”88% of deaths from diarrhea occur because of unsafe water, inadequate sanitation and poor hygiene”. Quoted from: World Health Organization (n.d) *Facts and figures: Water, sanitation and hygiene links to health*: http://www.who.int/water_sanitation_health/publications/factsfigures04/en/ (accessed 28.10.2013).

28. Disability-adjusted life year (DALY) is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. Source: Wikipedia (n.d.) *Disability-adjusted life year*: http://en.wikipedia.org/wiki/Disability-adjusted_life_year (accessed 28.10.2013).

29. Source: Government of India (n.d.) *Disability Adjusted Life Years In India, 2009 - Estimated Percentage Of DALY By Cause*: http://data.gov.in/dataset/disability-adjusted-life-years-india-2009-estimated-percentage-daly-cause (accessed 28.10.2013).

Less than one in thousand cases of diarrhea is fatal,[30] but it can be quite dangerous to children with as many as a quarter of a million children under five dying each year of diarrhea in India.[31] And even though the vast majority of children fortunately survive, repeated episodes of diarrhea make them vulnerable to other diseases and to malnutrition. According to UNICEF: *"children in [India] are shorter and more underweight because their bodies use up all energy to fight frequent infections, lowering their strength and growth"*.[32]

Children playing in Colony no. 5 in Chandigarh. Photo © Henrik Valeur, 2011.

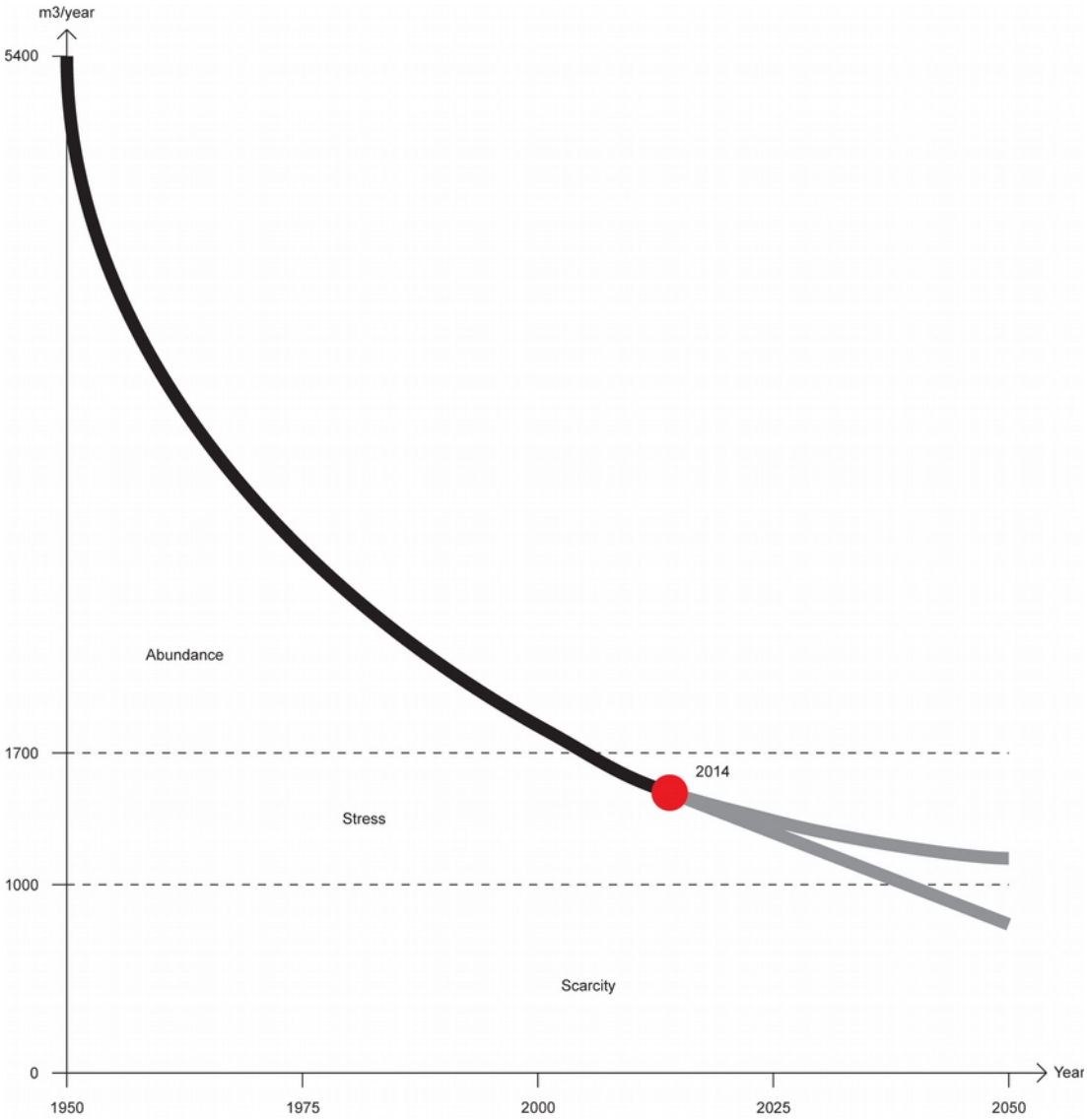
30. About 4 billion cases of diarrhea per year cause 1.8 million deaths worldwide. Source: UNICEF (n.d.) *Common water and sanitation-related diseases*: http://www.unicef.org/wash/index_wes_related.html (accessed 28.10.2013).

31. 237.482 children under 5 years died of diarrhea in India in 2008. Source: Robert E Black et al. (2010) *Global, regional, and national causes of child mortality in 2008: a systematic analysis*.

32. Quoted from: *Contaminated water stunting growth of Indian kids*. Hindustan Times, 14 February 2013: http://www.hindustantimes.com/India-news/NewDelhi/Contaminated-water-stunting-growth-of-Indian-kids-UNICEF/Article1-1011753.aspx

2. Water stress

Until quite recently India enjoyed abundant water resources, but population growth, overexploitation and pollution has led to a situation where the demand for water is increasingly exceeding supply.



Water availability per capita in India (1950 – 2050). In 1950, each Indian had on average 5.400 m^3 of water available per year. In 2011, that figure had dropped to just 1.545 m^3. The threshold for water stress is set at 1.700 m^3 and for water scarcity at 1.000 m^3. Sources: UNICEF, FAO and SaciWATERs (2013) ***Water in India: Situation and Prospects*** and Upali A. Amarasinghe, Tushaar Shah and K. Anand (2008) *India's Water Supply and Demand from 2025-2050: Business- as- Usual Scenario and Issues*. Future projections by UNICEF (high) and Henrik Valeur (low). Image © Henrik Valeur, 2013.

The country is currently using 634 billion cubic meters of water per year, according to official estimates, while the utilisable resources of water[33] stands at 1.123 billion cubic meters or almost twice as much.[34] Other estimates, however, put the utilisable resources very close to current use.[35] Considering that the availability of water is very unevenly distributed in both spatial and temporal terms, this would mean that some regions already experience periodic water scarcity.

2.1 Variables

The monsoon season provides nearly 90 percent of India's total rainfall in just three months, causing flooding in some areas and drought in others.[36] The distribution of rainwater may be further skewed by climate change believed to be largely caused by the emission of greenhouse gasses of which cities contribute 70-80 percent.[37]

The water that flows through the rivers also varies greatly with the water-flow of just two rivers - the Ganges and the Brahmaputra - accounting for 60 percent of the total water-flow of rivers in India.[38] And since these two rivers only pass through the north/northeastern part of the country, the water-flow of rivers in other regions is often under immense stress, causing frequent disputes between neighboring states.[39]

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33. Utilisable resources of water include rainfall water and water from melting ice in the mountains that can be extracted from rivers, lakes and groundwater each year without affecting the availability. In other words, it indicates the limit for sustainable use of water.

34. Source: UNICEF, FAO and SaciWATERs (2013) *Water in India: Situation and Prospects*. The 1.123 Gm^3 of utilisable water comprises of 690 Gm^3 of surface water and 433 Gm^3 of replenishable groundwater resources.

35. "Narsimhan (2008) calculated the water budget using an evapotranspiration rate of 65 per cent as against the 40 per cent used in official estimates. The utilisable water for human use thus comes out to be 654 BCM [Gm^3], which is very close to the current actual water use estimate of 634 BCM reflecting an alarming situation." And "Garg and Hassan (2007) reveals that the assessment of utilisable water resources of India are overestimated to the range of 66 to 88%. The authors estimate the utilisable water resources as 668 BMC". Both quotes from: UNICEF, FAO and SaciWATERs (2013) *Water in India: Situation and Prospects*.

36. See for instance: *Thousands feared dead after Indian monsoon causes extreme damage*. Washington Post, 25 June 2013: http://www.washingtonpost.com/blogs/capital-weather-gang/wp/2013/06/25/thousands-feared-dead-after-indian-monsoon-causes-extreme-damage/

37. 70% according to: UN Habitat (2011) *Hot Cities: battle-ground for climate change* and 80% according to: World Bank (2010) *Cities and Climate Change*.

38. The annual flow of water through the Ganges and the Brahmaputra has been estimated at 525 Gm^3/year and 585 Gm^3/year respectively, while the total amount of water flowing through all the rivers of India has been estimated at 1.869 Gm^3/year. Source: Strategic Foresight Group (2010) *The Himalayan Challenge: Water Security in Emerging Asia*.

39. Such as the dispute between the states of Karnataka and Tamil Nadu over water from the Kaveri (Cauvery). See: Wikipedia (n.d.) *Kaveri River water dispute*: http://en.wikipedia.org/wiki/Kaveri_River_water_dispute (accessed 28.10.2013). Other interstate disputes have occurred over water from Narmada, Yamuna, Godavari and Krishna, Ravi and Beas. In addition, the distribution of river water regularly causes disputes with neighboring countries (especially Pakistan and Bangladesh).

The pollution of rivers, streams, lakes and wetlands has made India increasingly dependent on groundwater.[40] Thus 1/4 of the world's total use of groundwater can be attributed to India, making it the largest groundwater user in the world.[41] But groundwater is also very unevenly distributed with some regions being naturally arid while others experience water shortage because of overexploitation.[42]

2.2 Inequality

The costs of clean water will most likely rise, perhaps even dramatically, as it becomes more scarce, which may also affect the costs of food. Subsistence may thus become much more costly.

The poor are already often paying more for water than the rich[43] because large numbers don't have access to public water, which is provided at a subsidized rate. In fact, according to a World Bank study: *"40% of the poor […] do not use any public water services"*.[44] Instead they have to rely on more expensive water from private suppliers.[45]

Apart from not providing much relief to the poor, artificially low tariffs on public water may also discourage people with access to save it. And without increased revenues maintenance and management of public water systems will likely remain poor, further contributing to the loss and waste of water.

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40. "The fact is that groundwater now supplies water to about 70% of the irrigated area, and about 80% of domestic water supplies." Quoted from: World Bank (2005) *India's Water Economy: Bracing for a Turbulent Future*.

41. Source: World Bank (2010) *Deep Wells and Prudence: Towards Pragmatic Action for Addressing Groundwater Overexploitation in India*.

42. In the states of Punjab, Rajasthan and Haryana the annual use of groundwater exceeds the net annual groundwater availability by respectively 145%, 125% and 109%. Source: World Bank (2010) *Deep Wells and Prudence: Towards Pragmatic Action for Addressing Groundwater Overexploitation in India*.

43. Source: *The poor pay more for water than the rich*. Livemint, 2 May 2009: http://www.livemint.com/Politics/mE6OiUi59ioGqDoHrd8yUP/The-poor-pay-more-for-water-than-the-rich.html

44. Quoted from: Usha P. Raghupati and Vivien Foster (2005) *Water tariffs and subsidies in South Asia: a scorecard for India*.

45. Private water supply is a huge industry in India: "Annual revenues from the tanker water economy in these six cities [Indore, Nagpur, Bangalore, Jaipur, Ahmedabad and Chennai] alone are reported to be in the region of Rs 100 crore [1 billion]. Extend the figure to other cities across the country and this may well be the biggest informal industry, thriving solely on the failed municipal water supply system." Quoted from: Sudhirendar Sharma (n.d.) *India's water future: Dry days ahead*: http://infochangeindia.org/agenda/the-politics-of-water/indias-water-future-dry-days-ahead.html

2.3 The water footprint

Still, the average Indian water footprint[46] (of consumption) is about one thousand cubic meters per year while that of an American is almost three thousand.[47]

Much of this difference can be explained by the very large number of vegetarians making India the country with the lowest consumption of meat per capita in the world. By contrast, Americans have the second highest consumption of meat.[48] And the water footprint of meat is many times bigger than that of vegetables.[49]

Thus, despite being home to 18 percent of the world's population India's water footprint (of production) is less than 13 percent of the world's total.[50] Unfortunately the country only holds 4 percent of the world's renewable water resources.[51]

To make matters worse, India depends much more on surface and groundwater resources than the rest of the world, while it makes much less use of rainwater.[52]

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46. The water footprint is a measure of human consumption and contamination of freshwater resources.

47. In the period 1996-2005 the average global per capita footprint was 1.385 m^3/year. In India it was 1.089 m^3/year and in the US it was 2.842 m^3/year. Source: Mekonnen, M.M. and Hoekstra, A.Y. (2011) *National water footprint accounts: the green, blue and grey water footprint of production and consumption*.

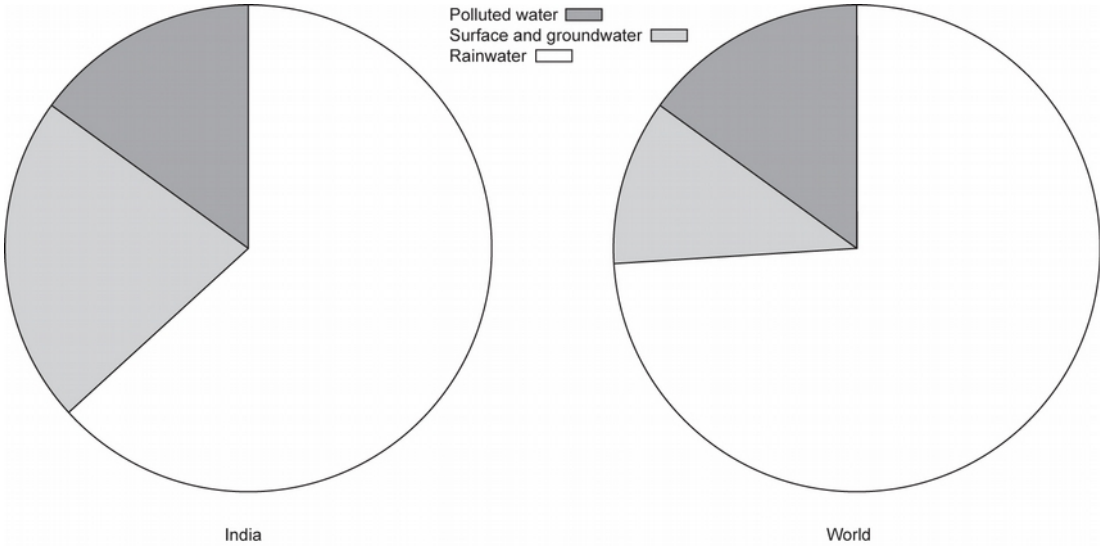
48. According to figures from the UN Food and Agriculture Organisation, the average American consumed 125.4 kg of meat per year while the average Indian consumed only 3.2 kg. Source: *Kings of the carnivores*. The Economist, 30 April 2012: http://www.economist.com/blogs/graphicdetail/2012/04/daily-chart-17

49. The water footprint of beef, pork and poultry is respectively 15.400, 6.000 and 4.330 l/kg while the water footprint of wheat, rice and potatoes is respectively 1.827, 1.670 and 290 l/kg. Source: Water Footprint Network: http://www.waterfootprint.org (accessed 28.10.2013).

50. The global water footprint (of production) in the period 1996-2005 was 9.087 Gm^3/year while that of India was 1.182 Gm^3/year. Source: Mekonnen, M.M. and Hoekstra, A.Y. (2011) *National water footprint accounts: the green, blue and grey water footprint of production and consumption*.

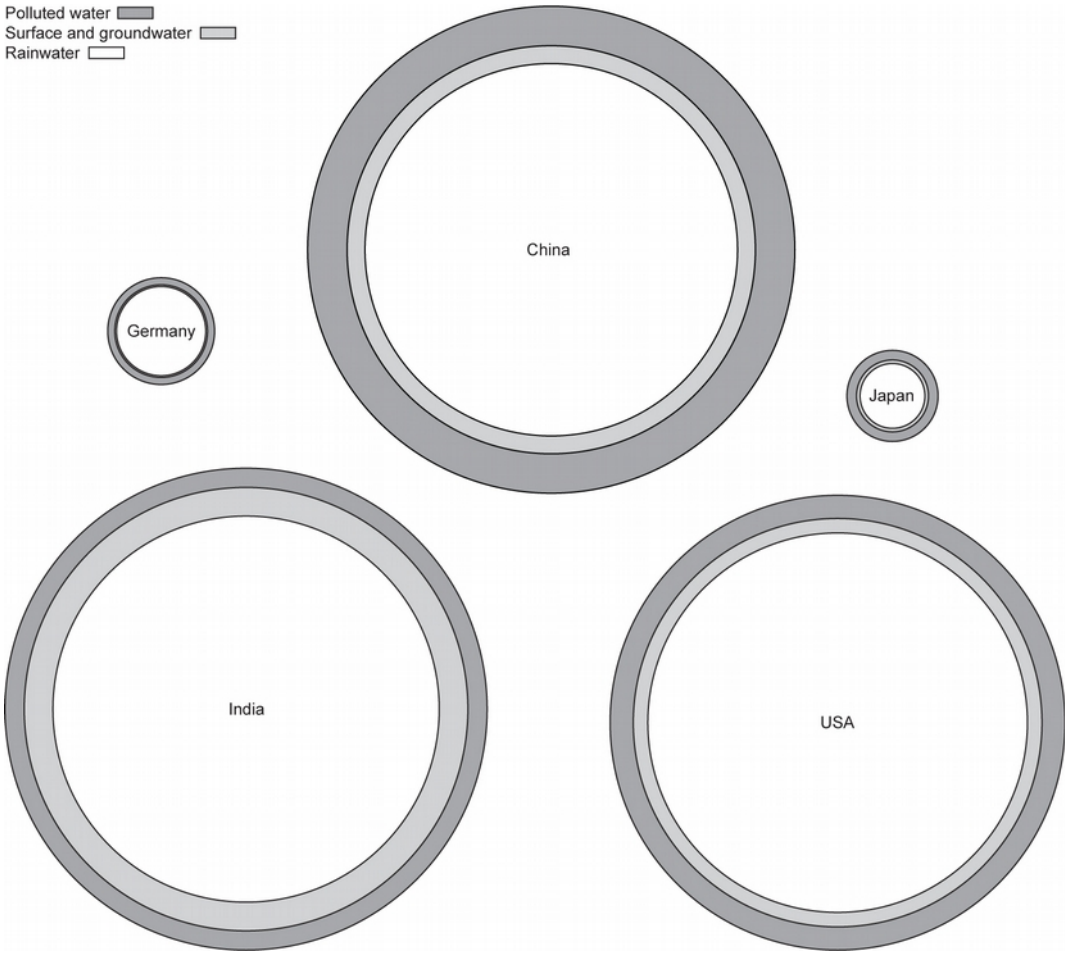
51. Source: Ministry of Water Resources (2012) *Draft for National Water Policy*.

52. Out of India's total water footprint (of production) 64% is rainwater (green), 21% is surface and groundwater (blue), and 15% is polluted water - or, more precisely, the volume of water required to dilute pollutants (grey). The world average is 74% rainwater, 11% surface and groundwater, and 15% polluted water. Source: Mekonnen, M.M. and Hoekstra, A.Y. (2011) *National water footprint accounts: the green, blue and grey water footprint of production and consumption*.



The 3 components of the water footprint (of production) in 1996-2005. India's total water footprint (of production) was 1.182 Gm^3/year or 13% of the world's total. Of this 15% was grey (polluted water), 21% was blue (surface and groundwater) and 64 percent was green (rainwater). The world's total water footprint (of production) was 9.087 Gm^3/year. Of this 15% was grey, 11% was blue and 74% was green. Source: Mekonnen, M.M. and Hoekstra, A.Y. (2011) *National water footprint accounts: the green, blue and grey water footprint of production and consumption*. Image © Henrik Valeur, 2013.

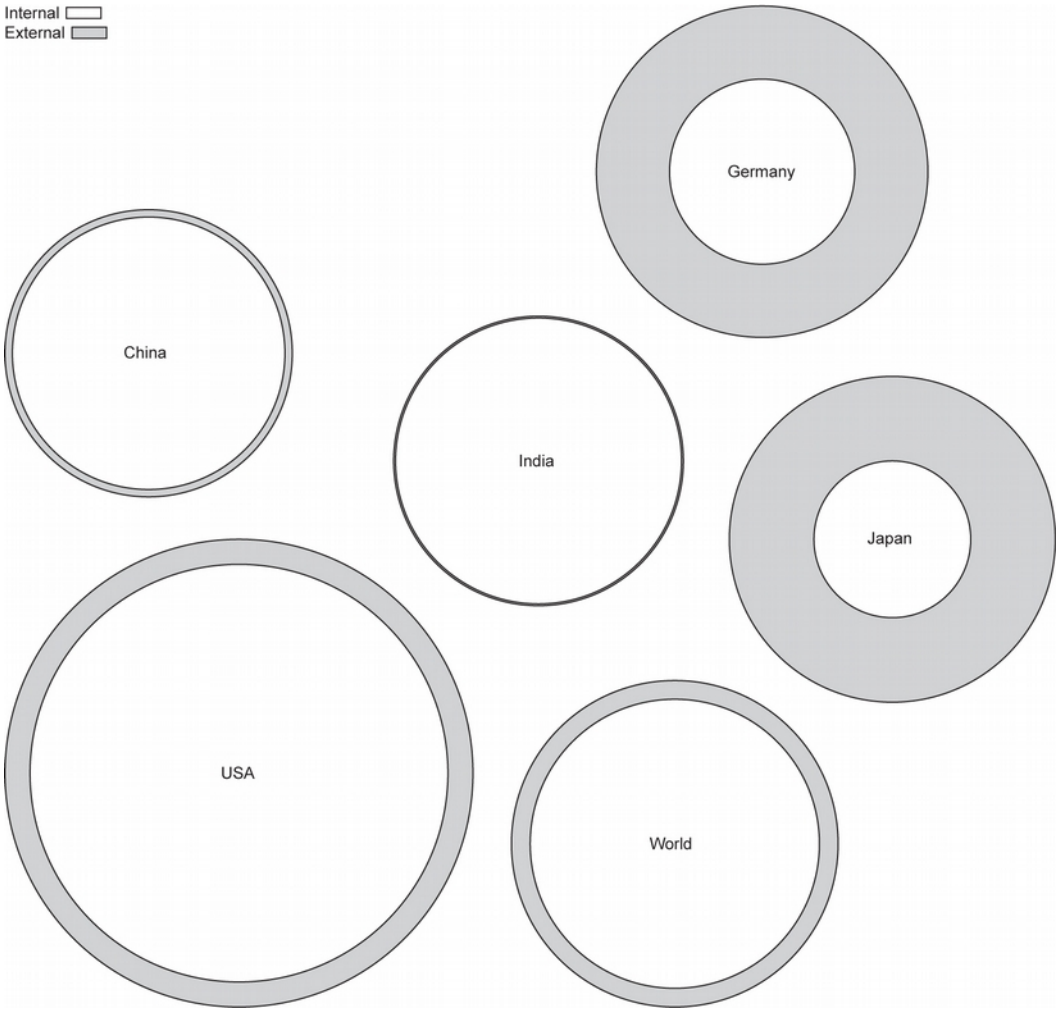
Stream in Chandigarh. Photo © Henrik Valeur, 2011.



The total water footprint (of production) and its 3 components in 1996-2005. India's blue (surface and groundwater) footprint was 243 Gm^3/year, which was almost the same as that of China (142 Gm^3/year) and the United States (117 Gm^3/year) combined. China's grey (polluted water) footprint was 360 Gm^3/year, which was almost the same as that of the United States (204 Gm^3/year) and India (180 Gm^3/year) combined. The United States' total water footprint was 1.053 Gm^3/year, which was more than ten times the total water footprint of Germany (58 Gm^3/year) and Japan (42 Gm^3/year) combined and almost as much as that of China (1.207 Gm^3/year) or India (1.182 Gm^3/year) despite its population being only about 1/4 of China's or India's. "The grey water footprint estimates in this study are to be considered as conservative", according to the authors. The grey water footprint is polluted water or, more precisely, the amount of water needed to dilute pollution. Source: Mekonnen, M.M. and Hoekstra, A.Y. (2011) *National water footprint accounts: the green, blue and grey water footprint of production and consumption*. Image © Henrik Valeur, 2013.

In addition to having considerable less water resources per person than the world average, India exports a signi ficant portion of its water, especially through agricultural products,[53] while only a small fraction of its water footprint (of consumption) stems from imported products (external).

53. The water footprint related to India's import of agricultural products (28 Gm^3/year) is only 1/4 of the water footprint related to its export of agricultural products (114 Gm^3/year), which is about 10 percent of its total water footprint of production (1.182 Gm^3/year). Source: Mekonnen, M.M. and Hoekstra, A.Y. (2011) *National water footprint accounts: the green, blue and grey water footprint of production and consumption*.



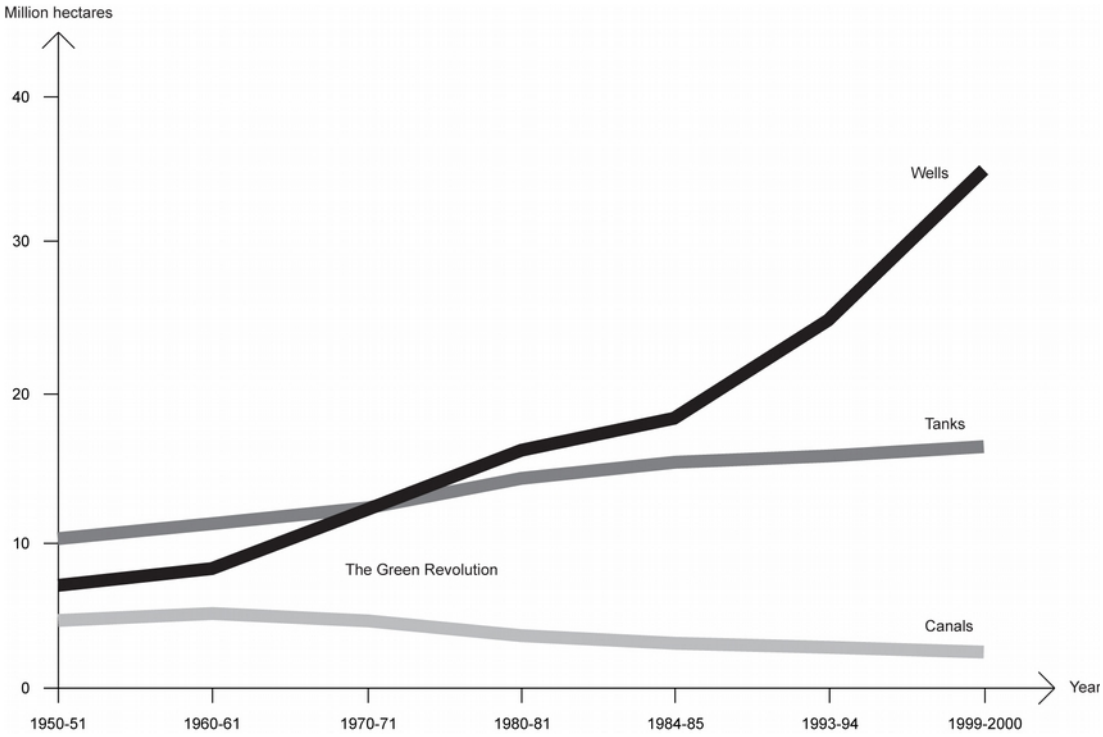
Water footprint (of consumption) from internal and external sources in 1996-2005. India's water footprint (of consumption) was 1.089 m^3/year/capita or less than the world average (1.385 m^3/year/capita) and 97.5% was internal. Japan's water footprint (1.379 m^3/year/capita) was very close to the world average but only 23% was internal. The United States' water footprint (2.842 m^3/year/capita) was more than double the world average but 80% was internal, which was close to the world average of 78%. Source: Mekonnen, M.M. and Hoekstra, A.Y. (2011) *National water footprint accounts: the green, blue and grey water footprint of production and consumption*. Image © Henrik Valeur, 2013.

2.4 Farming

Since rainfall in India is erratic farmers used to construct common systems of tanks and canals to collect and distribute water for irrigation, but following "the green revolution" and the provision of subsidized electricity for drilling and pumping water, farmers increasingly began to use groundwater from private wells for irrigation.

This has not only made farming more efficient but also enabled farmers to cultivate more land.

Today *"more than 60 percent of irrigated agriculture in the country is dependent on groundwater, with the crop water productivity of groundwater irrigated farms being almost twice that of surface water-irrigated farms."* As a result, the groundwater table is fast declining in many parts of the country and *"an increasing number of aquifers [are reaching] unsustainable levels of exploitation"*.[54]



Irrigated agricultural land in India by source of water for irrigation (1950-2000). The amount of agricultural land that was being irrigated with water from wells more than tripled from the inception of "the green revolution" in the late 1960's through the end of the millennium while the amount of agricultural land being irrigated with water from tanks and canals remained more or less constant during the same period. Source: World Bank (2010) *Deep Wells and Prudence: Towards Pragmatic Action for Addressing Groundwater Overexploitation in India*. Image © Henrik Valeur, 2013.

Decreasing levels of groundwater and increasing levels of pollution of the surface water makes farming ever more expensive and a growing number of farmers now find themselves trapped in debt, which may explain the unusual high numbers of suicides among Indian farmers in recent years.[55]

54. Both quotes from: World Bank (2010) *Deep Wells and Prudence: Towards Pragmatic Action for Addressing Groundwater Overexploitation in India*.

55. Each year since 2001 more than 15.000 Indian farmers have committed suicide. Source: *Farmers' suicide rates soar above the rest*. The Hindu, 18 May 2013: http://www.thehindu.com/opinion/columns/sainath/farmers-suicide-rates-soar-above-the-rest/article4725101.ece

In some places the groundwater table is now so low that farmers - the ones who can afford it - *"are using modified oil-drilling technology to reach water, going as deep as 1,000 feet in some locations"*.[56]

Others farmers are selling groundwater from private wells for consumption in cities instead of using it for irrigation. And while more than 90 percent of the total water consumption in India can be attributed to agricultural production,[57] an increasing share of that produce goes to feed a growing urban population. In addition, most of the water used for industrial production and most of the domestic water use can be attributed to cities.

2.5 Urbanization

Urban growth may adversely affect the water situation in India because urban dwellers use more water, and therefore generate more wastewater, than rural dwellers,[58] while indirectly contributing to the increased consumption and contamination of water through the demand for water intensive agricultural and industrial products.[59]

The modernization of Indian cities, including the provision of running water supply, and the introduction of "urban" amenities such as flush toilets, bath tops and washing machines lead to increased water consumption. Still only half of the urban population in India has access to piped water on premises[60] and most cities only get piped water for a few hours per day and some cities only on some days.[61]

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56. Quoted from: *The real threat to our future is peak water*. The Guardian, 6 July 2013: http://www.theguardian.com/global-development/2013/jul/06/water-supplies-shrinking-threat-to-food

57. The water footprint (of consumption) of agricultural products in India is 1.013,9 m^3/year per capita, or 93% of the total water footprint per capita. Source: Mekonnen, M.M. and Hoekstra, A.Y. (2011) *National water footprint accounts: the green, blue and grey water footprint of production and consumption*.

58. The recommended norms for water supply in India is 30 - 70 l/day per capita for rural areas and villages and 100 - 150 l/day per capita for towns and cities. Source: National Institute of Hydrology: http://www.nih.ernet.in/rbis/india_information/drinking.htm (accessed 10.12.2013).

59. Water intensive agricultural products include sugar, fruit, vegetables, dairy and meat. Source: Liza Bowen et. al. (2010) *Dietary Intake and Rural-Urban Migration in India: A Cross-Sectional Study*. In addition to soft drinks and other processed beverages.

60. 198 million out of a total urban population of 388 million have access to piped water on premises in India. Source: WHO and UNICEF (n.d.) *Joint Monitoring Programme for Water Supply and Sanitation*: http://www.wssinfo.org (accessed 22.10.2013).

61. Source: *Only 2 Indian cities have continuous water supply*. Business Standard, 23 March 2010: http://www.business-standard.com/article/economy-policy/-only-2-indian-cities-have-continuous-water-supply-110032300101_1.html

As a result, more and more water is supplied from private - often unregulated and illegal - bore wells,[62] which greatly contributes to the depletion of groundwater reserves.

Public water tap in Bangalore. Photo © Henrik Valeur, 2013.

However, there are great opportunities for water conservation and recycling in cities because the high concentration of people makes it technically feasible to provide efficient distribution of water and wastewater treatment for everyone.

Meanwhile, the widespread use of flat roofs in Indian cities make them ideal for rainwater harvesting for domestic, industrial and municipal use, including private and community kitchen gardens to offset consumption and contamination of water from conventional agriculture.

62. The number of private bore wells in India has been estimated at 25-30 million. This includes wells for agricultural, industrial and domestic use. Source: *Source of Life*. The Hindu, 18 October 2013: http://www.thehindu.com/features/homes-and-gardens/source-of-life/article5247667.ece. For a description of private water supply in the city of Hyderabad, see: *The great water robbery*. Times of India, 17 May 2012: http://articles.timesofindia.indiatimes.com/2012-05-17/hyderabad/31748085_1_water-board-tanker-owners-private-tanker-operators

3. Conclusion

India is prone to natural disasters caused by too much water, such as torrential rain and flooding rivers. This may be further aggravated by climate change that may also lead to rising sea levels and melting glaziers. However it is the lack of water that poses the most serious, long-term threat to life on the subcontinent.

India used to have abundant water resources but during the second half of the 20th century, as the population tripled, the amount of water available per person was reduced to 1/3. This trend seems to continue in the 21st century with the country recently reaching the level of water stress and the prospect of widespread scarcity within a few decades.

Apart from population growth, the main reasons why India is running out of water are:

1. Pollution of surface and groundwater (mainly caused by human activities)
2. Depletion of groundwater (solely caused by human activities)
3. Uneven and unreliable distribution of rainwater (partly caused by human activities)

The effects of pollution, overexploitation and drought are already being felt, especially among the poor, ranging from serious health problems to suicides among farmers. But it may also result in conflicts between people, states and countries, cities and villages.

The so-called “green revolution” has adversely affected the water situation in India, but the introduction of chemical pesticides and fertilizers, water intensive crops and groundwater irrigation in the late 1960’s also helped make India self-sufficient with food. In fact, since Independence in 1947, India hasn’t experienced any severe famine.[63]

63. India has experienced many severe famines, such as the Indian famine of 1896-97, in which five million people perished, and the Bengal famine of 1943, which claimed another five million lives from starvation and epidemics, but since the beginning of “the green revolution” in the late 1960s, in fact since independence in 1947, India hasn’t experienced any severe famine.

It could thus be argued that “the green revolution” prevented hunger but created thirst instead. Which may eventually lead to hunger again.[64]

Until now most of the population growth in India has taken place in rural areas but in the future almost all of the growth is expected to take place in urban areas.[65]

Given the adverse implications of population growth on water availability a positive aspect of the urban transition of India is that urban dwellers have fewer children than their rural counterparts.[66]

Another positive aspect is that this transition doesn’t seem to give people more appetite for meat, at least not nearly as much as it has in China.

And while urban dwellers do contribute more to the pollution and depletion of water and to climate change than rural dwellers, Indian cities have a large - and largely unexploited - potential for water conservation and water recycling, including more efficient distribution of water, better wastewater treatment and more rainwater harvesting.

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64. Water scarcity may lead to famine because it takes much more water to satisfy hunger than to satisfy thirst: “We drink on average four litres of water per day, in one form or another, but the food we eat each day requires 2,000 litres of water to produce.” Quoted from: *The real threat to our future is peak water*. The Guardian, 6 July 2013: http://www.theguardian.com/global-development/2013/jul/06/water-supplies-shrinking-threat-to-food

65. During the second half of the 20th century the population of India almost tripled from 372 million in 1950 to 1.054 million in 2000. 2/3 of this growth took place in rural areas. During the first half of the 21st century the population is expected to grow by almost the same number of people to 1.692 million, but less than 10% of this growth is expected to take place in rural areas. Source: United Nations, Department of Economic and Social Affairs (n.d.) *World Urbanization Prospects: The 2011 Revision*: http://esa.un.org/unup/CD-ROM/Urban-Rural-Population.htm (accessed 05.11.2013). Population figures differ slightly between different sources.

66. This also explains why population growth in relative numbers is expected to slow down significantly from 183% between 1950 and 2000 to 61% between 2000 and 2050. Source: United Nations, Department of Economic and Social Affairs (n.d.) *World Urbanization Prospects: The 2011 Revision*: http://esa.un.org/unup/CD-ROM/Urban-Rural-Population.htm (accessed 05.11.2013).