Status of virtual water trade from India

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Virtual water refers to the water required in the production of a commodity or service. The adjective 'virtual' refers to the fact that most of the water used in the production of a commodity, is in the end not contained within the product. When goods and services are exchanged, so is the virtual water and this is referred to as virtual water trade. Virtual water trade is becoming an important component of water management on the global as well as regional level, particularly in regions where water is scarce.

With a rapidly growing population and improving living standards in India, the water requirement of the country is increasing and the per capita availability of water resources is reducing day by day. There is a need for proper planning of water resource utilization for the country so that the gap between the water availability and requirement may be minimized. Virtual water trade is one of the alternatives to reduce water consumption. This article presents a review of virtual water content of various products estimated for India and gives the status of virtual water trade taking place from India.

Keywords: Business process outsourcing, trade, virtual water, water footprint.

WATER is required for the production of food such as cereals, vegetables, meat and dairy products and other commodities such as steel, petrol, paper, etc. Virtual water was defined at the beginning of the 1990s by Allan[1] as 'water embedded in commodities'. The amount of water consumed in the production process of an agricultural or industrial product is called the 'virtual water' contained in the product. This water is 'virtual' because it is not physically contained anymore in the product. The real water content of products is generally negligible if compared to the virtual water content. For example, to produce 1 kg of wheat in India, we need 1654 l of water, whereas to produce 1 kg of maize 1937 l of water is required. Producing livestock products generally requires more water per kg of the product. For instance, 1 kg of cheese requires about 5000–7000 l of water[2]. A cup of coffee uses about 140 l of water, whereas tea requires only one-eighth of that quantity. About 3200 l of water is required[3] to produce a 32-megabyte computer chip of 2 g.

The virtual water concept has two types of practical uses[4]. First, virtual water can be seen as an alternative source of water and thus can be an instrument to achieve regional water security. Virtual water trade can be an instrument in solving geopolitical problems and even prevent wars over water[1,5]. Secondly, the virtual water content of a product tells something about the environmental impacts of consuming the product. The World Water Council states 'showing people the virtual water content of various consumption routes will increase the water awareness of people'. The daily amount of water we consume through our food is much more than we use daily for drinking, washing, sanitation and other household tasks.

Some countries of the world do not have adequate water to meet their current and projected water needs, while in some other countries available water is more compared to the demands. Further, in big countries there are regions of surplus or deficient water availability. The water-deficit countries/regions in countries can overcome the water scarcity problem through import of water (virtual) by importing food-grains, etc. from water-surplus countries/regions in countries instead of producing it locally. Of course, in reality things are not so simple and additional questions of food security, energy security, employment, etc. enter in the picture.

Despite the intuitive appeal of the concept of virtual water, the idea has some limitations too. Analysis of country-level data[6] on freshwater availability and net virtual water trade of 146 nations showed that a country's virtual water trade is not determined by its water situation. In many instances, virtual water flows out of 'water-poor' but 'land-rich' countries to 'water-rich' and 'land-poor' countries. For a water-poor but land-rich country, virtual water import offers little scope as a sound water management strategy, since what is often achieved through virtual water trade is improved 'global land-use efficiency'[6]. Further, if a nation facing water shortage also faces food shortage, it will import the kind of food its population requires rather than importing food with the maximum virtual water content. Importing countries also may stay away from large scale virtual water import because of the fear of paying 'political ransom' to the exporter of virtual water in case of a con-

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frontation[7]. Also for many countries like India and China, self-sufficiency in food is still a national priority.

According to Horlemann and Neubert[8], virtual water strategy is suitable more as a complement to other necessary steps in sustainable water management and tends to be harmful as a separate strategy. Including virtual water as a policy option requires thorough understanding of the impact and interactions of virtual water trade on the local, social, economic, environmental and cultural situation. According to Hofwegen[9], virtual water trade could deprive farmers and their families of their livelihoods, unless alternatives are developed in terms of crops or employment which save water. Virtual water trade should contribute to local, national and regional food security, which requires not only appropriate trade agreements that respect a nation's right to decide on food security measures, but also local distribution mechanisms ensuring access to food[9].

Virtual water content

Virtual water content of a product depends upon the technology and conditions of production. Considerable saving of water is possible if water-efficient technology is employed to produce the product. Further, water consumed in a production process also depends upon climate; more water is needed to produce each unit of a crop in arid climates compared to that in humid areas.

The virtual water content of various primary and processed crop products, livestock products and industrial products for different countries was estimated by Chapagain and Hoekstra[10]. While computing the virtual water content of products, a distinction is made between primary products (e.g. vegetables), processed products (e.g. sugar), and transformed products (e.g. cheese). Some processes may yield multiple products and in this case, total quantity of water used is allocated amongst these. Further, not all products require water and for such items virtual water content is nil. The virtual water content of a crop in a country is calculated as the ratio of total water used for the production of the crop to the total volume of the crop produced in that country. Crop water use is assumed to be equal to the crop water requirement, which is calculated by accumulation of data on daily crop evapotranspiration over the complete growing period. Crop water requirements for different crops have been calculated[10] using the CROPWAT model of the Food and Agriculture Organization (FAO), United Nations.

The virtual water content of an animal, at the end of its lifespan, is defined as the total volume of water that was used to grow and process its feed, for its drinking needs, and to clean its housing and the like. The virtual water content of a processed product depends on the virtual water content of the primary item or live animal from which it is derived. The virtual water content of the primary crop or live animal is distributed over the different products from that specific crop or animal. Virtual water content of industrial products is estimated on a country-average basis, by dividing the individual water withdrawn by a particular country with the value added from the industrial sector for that country. Detailed methodology to estimate the virtual water content of various primary and processed crop products, livestock products and industrial products is available[10] at http://www.waterfootprint.org/Reports/Report16.pdf.

Table 1 gives the virtual water content of selected crops and livestock products calculated for India[10]. The average virtual water content of industrial products for India is estimated[10] as 4.75 l/rupee or 0.215 cubic m/US dollar. The virtual water content of various crop and crop products is calculated considering the country's average climate data. Some of the data used are of the capital city (New Delhi). As the climate in India significantly varies spatially, the virtual water content of various crops and crop products will also have large spatial variations. Another shortcoming of the above assessment is that the estimates of virtual water content of crops are based on crop water requirements, which leads to overestimates in those cases where actual water availability is lower than the crop water requirement. The calculations could be improved using the actual water use by crops as a basis, which will require more specific data per crop. Such calculations, in the first instance, may be carried out for each state.

Virtual water trade

Virtual water trade refers to the transfer of water (virtual) that takes place during trade of various goods and services. Virtual water trade is not new; it is as old as food trade. Virtual water trade is becoming an important concept of water management on a global as well as regional level, particularly in regions where water is scarce[2]. Many countries are involved in virtual water trade consciously relating to water policies. Some countries where these conscious choices have been made are Morocco, Jordan, Israel and Egypt, which are importers of virtual water. Many studies[10–13] have estimated the magnitude of virtual water trade between various countries. In these studies, the basic approach has been to multiply trade volumes by their associated virtual water content. In a recent estimate[10], global virtual water flow was found to be of the order of 1625×10^9 m^3/yr (Gm^3/yr) during the period 1997–2001, of which 61% was related to international trade of crops, 17% to trade of livestock and livestock products, and the remaining 22% to trade of industrial products.

The different water productivities – the volume of water required per unit of product – for different countries give rise to the concept of national and global water saving through international virtual water trade. However, according to de Fraiture *et al.*[14], this is not always true and sometimes trade in virtual water may lead to the 'loss' of water resources if the importer can produce the commodity

Table 1. Virtual water (VW) content of crop and livestock products for India (1997–2001)[10]

Product	VW content (cubic m/tonne)	Product	VW content (cubic m/tonne)
Crop and crop products			
Wheat	1654	Palm oil	5169
Rice (paddy)	2850	Sunflower/safflower oil	8541
Rice (husked)	3702	Mustard oil	4643
Barley	1966	Linseed oil	19159
Maize	1937	Banana	415
Millet	3269	Orange	364
Sorghum	4053	Lemon and lime	611
Sugarcane	159	Grapefruit	411
Lentils	6652	Apple	1812
Soybeans	4124	Pear	1287
Oats	1597	Apricot	2424
Rye	901	Cherry	2532
Jute	2823	Peach	1564
Cotton lint	18694	Plum	1907
Potatoes	213	Grapes	238
Sweet potato	277	Watermelon	362
Beans (green)	487	Mango/guava	1525
Beans (dry)	8335	Pineapple	305
Castor beans	9807	Papaya	922
Urad/mung/gram beans	3078	Dates	3030
Peas (green)	178	Avocado	1284
Peas (dry)	3040	Strawberry	296
Chick pea	2712	Almond (in shell)	9769
Pigeon pea	4066	Cashewnut	15340
Cabbage	180	Walnut (in shell)	11721
Onion (fresh)	214	Arecanut (betal)	9985
Onion (dry)	538	Groundnut (in shell)	3420
Tomato	302	Coconut	2255
Cauliflower	100	Coffee (roasted)	14500
Pumpkin, squash, gourd	238	Coffee	12180
Cucumber and gherkin	357	Cocoa beans	13775
Garlic	1268	Cocoa powder	8994
Carrot/turnip	192	Tea (black)	7002
Spinach	144	Tea (green)	1804
Sunflower seed	4304	Sugar (raw)	1301
Safflower seed	6864	Sugar (refined)	1391
Sesame seed	8415	Clove	61304
Cotton seed	8264	Turmeric	1556
Linseed	11080	Pepper	8333
Rape seed	2618	Ginger	1556
Corinader seed	949	Tobacco	2627
Groundnut oil	8875	Natural rubber	7626
Olive oil	21106	Beer	411
Coconut oil	3051	Grape wine	341
Livestock and livestock products			
Bovine	7386	Milk powder	6368
Swine	4119	Yogurt/milk product	1592
Sheep	3397	Buttermilk	2068
Goat	3018	Cheese	6793
Fowl/poultry	6024	Egg (birds)	7531
Horse/ass/mule	2849	Leather (bovine)	17710
Milk (fat <1%)	1369	Goat meat	5187
Milk (fat >1% and <6%)	1415	Sheep meat	6692
Milk (fat >6%)	2547	Chicken meat	7736

with greater water efficiency. Chapagain *et al.*[7] have estimated global water saving of the order of 352 Gm^3/yr (average over the period 1997–2001) from the international trade of agricultural products.

Virtual water trade from India

The virtual water trade for India has been estimated by various authors over the years. Hoekstra and Hung[11] estimated net virtual water export from India, related to trade of crops of the order of 32.2 Gm^3/yr during the period 1995–99. During the same period, net virtual water export related to trade of livestock[2] was estimated as 2.3 Gm^3/yr. During these five years, India exported 191.8 Gm^3 of virtual water and imported 19.5 Gm^3 of virtual water, leading to a net export of 172.3 Gm^3. India ranked sixth among countries with net export. Both these studies[2,11] considered virtual water content of the products from the exporting countries. Zimmer and Renault[15] estimated the amount of virtual water import and export from India related to crop products to be of the order of 31 and 8 Gm^3/yr, respectively, for the year 1999. According to these data, India is a net import country. This study estimated the trade considering the virtual water content in importing countries.

According to Chapagain and Hoekstra[10], India has exported 42.5 Gm^3/yr of virtual water with net export of 25.4 Gm^3/yr during the period 1997–2001. Out of the total export of 42.5 Gm^3/yr, crop trade contributed 76%, livestock 8% and industrial products 16%, whereas out of total import, 81% trade was related to crop, 2% to livestock and the remaining 17% to industrial products. Soybean and palm oil were the major crops for virtual water export and import respectively. During this period, India was among the top 15 gross virtual water exporters and among the top ten net virtual water exporters[10]. Chapagain *et al.*[16] calculated virtual water flow from India related to export of cotton products as 25.66 Gm^3/yr which consists of 16.83 Gm^3 of green water (effective rainfall), 5.75 Gm^3 of blue water (irrigation water) and the remaining 3.08 Gm^3 for dilution water. Dilution water is the volume of water required to dilute waste flow to such an extent that the quality of water remains within the agreed quality standards. One can note that there are large differences in the computation of virual water trade from India.

FAO provides trade data (import and export) for crop and livestock products for various countries in its database FAOSTAT (http://faostat.fao.org). Considering the data on import and export from India, the virtual water trade for India has been calculated for the five-year period 2001–05 (Table 2). Note that the crop and livestock product import and export data also include the crop and livestock products received/given as food aid. The quantity of virtual water trade as given in Table 2 is calculated by multiplying the trade volume of a product with the virtual water content of that product for India, as calculated by Chapagain and Hoekstra[10]. As seen from Table 2, India has exported 228.61 Gm^3 of virtual water with an average of 45.72 Gm^3/yr and imported 358.27 Gm^3 of virtual water with an average of 71.65 Gm^3/yr during these five years. According to these calculations, India was a net importer of 25.93 Gm^3/yr of virtual water related to crop and livestock products during the period 2001–05.

Table 2. Virtual water trade related to crop and livestock products from India

Year	Export (Gm^3/yr)	Import (Gm^3/yr)	Net import (Gm^3/yr)
2001	34.62	68.85	34.22
2002	47.72	69.02	21.30
2003	47.32	68.43	21.11
2004	51.63	67.53	15.91
2005	47.32	84.44	37.12
Average	45.72	71.65	25.93

According to Asia Water Business[17], virtual water import policy may not be of relevance to India due to adverse socio-economic implications such as unemployment, but virtual water considerations can be integrated into various policies and practices. Kumar *et al.*[18] have stressed the need to assess virtual water in terms of its value in space and time and also to analyse how virtual water is considered at policy level on food trade, water management and agriculture. It may be added that virtual water is not considered as a water management tool by many investigators. While studying the available options to meet water needs of India in 2050, Gupta and Deshpande[19] have not considered virtual water import as an option.

Water dimension of business process outsourcing

In the field of information and communication, two important changes have taken place during the past decade. With the advent of modern means of communication, particularly the Internet, it has become extremely simple and efficient to transfer data across the world. Large volumes of data of the order of gigabytes can be transferred over long distances at a very small cost in a short time. The physical location of the two parties involved in data transfer is now immaterial. A natural fallout of this development is that if it is expensive to analyse data at the place where it is being generated or is to be used, data could be transferred to places where it is cheaper to analyse them. This has led to a revolutionary concept of Business Process Outsourcing (BPO). This is defined as the delegation of one or more business processes to an external service provider, who in turn owns, manages and administers the selected processes, based on defined and measurable performance metrics. In this concept, an organization transfers or outsources some non-core activities to places where it is cheaper to complete them.

Since the late 1990s, the industry BPO is continuing to grow worldwide as factors that force companies to focus on core competencies intensify. BPO is a boon to multinational companies, since it helps them in cutting costs and improving profit margins. These days, the tendency of companies to set up their production base or R&D centres in different parts of the world is increasing. Although the multi-national companies rarely consider water consumption while relocating jobs, BPO has a virtual water dimension also. When an employee located in a particular country is providing services to clients located in another country, his host country is exporting virtual water equal to the country's water footprint, the whereas client country is importing virtual water equal to its water footprint. If a company located in a water-scarce country resorts to BPO, then it is reducing the pressure on its natural resources by importing virtual water and virtual labour.

The availability of cheap and skilled manpower in many countries such as India, China and Ireland, has made them an attractive destination for multinationals to complete their non-core operations. In recent years, India has witnessed a rapid growth in the BPO industry. According to the National Association of Software Companies (NASSCOM) of India, the Indian BPO segment commands 2% of the global market. The market share is projected[20] to grow to 4.8% by the year 2008. Further, NASSCOM estimated that the Indian BPO industry employed 348,000 people by the year 2005. Estimates[21] place the workforce requirement of the BPO industry at 1 million staff by the year 2008.

Table 3 gives the past, present and future workforce in the BPO industry in India, compiled from various sources. Considering a virtual footprint of 980 cubic m/capita/yr for India[10], the volume of virtual water exported from India on account of BPO jobs can be computed (Table 3). Evidently, the quantum of water exported on account of BPO is steadily rising with time. It can be noted from Table 3 that India exported virtual water amounting to 341×10^6 m^3 (Mm^3) in year 2005. This export is expected to rise to 980 Mm^3/yr by 2008. A steep rise in water demand on account of BPO is expected by the year 2008. In the computations so far, additional water requirements have been worked out considering only the number of workers in the BPO industry. However, it can also be argued that consumption by the whole family of a worker should be taken into consideration. Following this argument and assuming a typical family size of three persons (spouse plus one dependent child), the demand immediately triples and the importance of this industry also magnifies. Of course, if any member of the family is involved in another job, his/her share of water consumption should not be considered.

During the early phases BPO offices were set up in metropolitan cities, but as the infrastructure in these cities is under pressure and office space is becoming more expensive, the trend is to set up these offices in smaller towns. Clearly, much of the expected future growth will come from smaller cities and planners will have to upgrade civic amenities, including water supply in these cities to meet the increased demands.

Table 3. Workforce in BPO industry in India and resultant virtual water export

Year	Number of employees in BPO sector	Volume of virtual water export (Mm^3/year)
2000	45,000	44.1
2001	70,000	68.6
2002	106,000	103.9
2003	171,000	167.6
2004	245,500	240.6
2005	348,000	341.0
2008	1,000,000	980.0

Water management in India – Role of virtual water

India is a country with a large geographical area (3.29 M km^2) and the culturable area is 1.43 M km^2. The annual average precipitation is about 4000 cubic km. There are large variations in climate and land productivity. Often, there are questions as to whether the regions with scarce rainfall should adopt water-guzzling crops. For example, Punjab is facing water scarcity. The number of dark blocks (where the exploitation of groundwater is more than 85% of the annual potential) in Punjab has increased from 64 in 1984–85 to 83 in 1997–98. Despite this, paddy is grown over extensive areas in Punjab and most of the harvest goes to the central grain pool. In this way Punjab is exporting large quantities of virtual water. At the same time, its neighbouring states claim that Punjab does not give them adequate water on the pretext that it is facing a water shortage. This paradox can only be explained by the fact that the farmers and the economy of the state earn through virtual water export, but they do not get anything by physical transfer of water.

The Northeastern region of the country is bestowed with high water resources potential. This region gets high rainfall and the Brahmaputra river flowing through this area, has surface water potential[22] of 677.41 cubic km. This river basin has large hydroelectric potential (≈ 34900 MW), which can be tapped and transmitted to other regions of the country having shortage of electric power. Transfer of water from the northeastern region to the other parts of the country is difficult due to topographical and other reasons. However, transfer of virtual water in the form of electricity will be somewhat easier (although there will be other issues). Besides meeting the much desired energy demands of the country, additional income to the Northeastern states can be used for their economic development.

Water footprint

Hoekstra and Hung[11] introduced the concept of water footprint. The water footprint of a country is defined as the volume of water needed for the production of goods and services consumed by the inhabitants of the country. Four major factors determining the water footprint of a country are: volume of consumption (related to gross national income), consumption pattern (high versus low meat consumption), climate (growth conditions) and agriculture practices (water-use efficiency).

Table 4. Composition of water footprint for India (1997–2001)[10]

Use of domestic water resources	Domestic water withdrawal (Gm^3/yr)		38.62
	Crop evapotranspiration (Gm^3/yr)	For national consumption	913.70
		For export	35.29
	Industrial water withdrawal (Gm^3/yr)	For national consumption	19.065
		For export	6.04
Use of foreign water resources	For national consumption (Gm^3/yr)	Agriculture goods	13.75
		Industrial goods	2.24
	For re-export of imported products (Gm^3/yr)		1.24
Water footprint	Total (Gm^3/yr)		987.38
	Per capita (cubic m/capita/yr)		980
Water footprint by consumption category	Domestic water (cubic m/capita/yr)	Internal water footprint	38
	Agriculture goods (cubic m/capita/yr)	Internal water footprint	907
		External water footprint	14
	Industrial goods (cubic m/capita/yr)	Internal water footprint	19
		External water footprint	2

The water footprint of a nation consists of both internal and external components. The volume of water used from domestic water resources to produce goods and services consumed by the inhabitants of the country constitutes the internal water footprint of a nation. The external water footprint of a country is the volume of water used in other countries to produce goods and services imported and consumed by the inhabitants of the country. The total water footprint of a nation is a useful indicator of a nation's call on the global water resources. At the consumer's level, it is useful to show people's individual footprint as a function of food diet and consumption pattern. The impact of consumption by people on the global water resources can be mapped with the concept of the water footprint. Based on the analysis of data of the years 1997–2001, the global water footprint[10,23] is calculated as 7450 Gm^3/yr, which is 1240 cubic m/capita/yr.

The water footprint for India has been estimated by Chapagain and Hoekstra[10] as 980 cubic m/captia/yr. The composition of the water footprint for India is given in Table 4. Internal water sources constitute 98.4%, whereas external water sources constitute 1.6% of India's water footprint. Consumption of agriculture goods contributes 94%, domestic water contributes 3.9% and industrial goods contribute the remaining 2.1%. In absolute terms, India has the largest footprint in the world, i.e. 987 Gm^3/yr. On per capita basis, USA has the largest water footprint with 2480 cubic m/yr per capita. Water footprint of worldwide cotton consumption was estimated as 256 Gm^3 of water per year[16]. For India, the water footprint related to consumption of cotton products is 31024 Mm^3/yr, which includes 30441 Mm^3/yr as internal and 583 Mm^3/yr as external water footprint. This footprint is the third largest in the world, after China and USA.

Conclusion

Virtual water trade is a new concept which is slowly gaining acceptance. At present, it is not used much in decision-making. There are numerous examples of countries which are facing water shortage, but are still involved in production processes that consume large quantities of water. Within countries also, there are regions of water deficit in which water-guzzling crops are being produced. Nevertheless, this is a useful concept which is likely to gain importance and wide applications in the future. Virtual water may become an additional consideration in deciding what to export/import. This concept can be useful in making agricultural choices within the country among various states. It may also be added that for evolving water-management policies, the concept of virtual water has to be used along with other aspects such as engineering, financial, social, food and energy security. A policy that has been evolved solely on virtual water consideration may not be optimal and acceptable.

According to the computations carried out by the authors for the period 2001–05, India has exported on an average of 45.72 Gm^3/yr and imported 71.65 Gm^3/yr with a net import of 25.93 Gm^3/yr of virtual water related to crop and livestock products. Thus for the crop and livestock sector, India is a net importer of virtual water. India is a vast country with large spatial variation in climate. Accordingly, virtual water content of various products, particularly agriculture goods, may vary greatly within India. There is a need to assess the virtual water content of various agriculture products for different agro-climatological divisions. There is also a need to estimate the virtual water trade between different states of the country. Moreover, current estimates of virtual water content and water footprint are quite approximate, which require refinement based on more data as well as improved methodology.

1. Allan, J. A., Fortunately there are substitutes for water, otherwise our hydro-political futures would be impossible. In *Priorities for*

Water Resources Allocation and Management, Overseas Development Administration (ODA), London, 1993, pp. 13–26.
2. Chapagain, A. K. and Hoekstra, A. Y., Virtual water trade: A quantification of virtual water flows between nations in relation to international trade of livestock and livestock products. In Virtual Water Trade: Proceedings of the International Expert Meeting on Virtual Water Trade (ed. Hoekstra, A. Y.), Value of Water Research Report Series No. 12, UNESCO-IHE, Delft, The Netherlands, 2003, pp. 49–76.
3. Williams, E. D., Ayres, R. U. and Heller, M., The 1.7 kilogram microchip: Energy and material use in the production of semiconductor devices. *Environ. Sci. Technol.*, 2002, **36**, 5504–5510.
4. Hoekstra, A. Y., Virtual water: An introduction. In Virtual Water Trade: Proceedings of the International Expert Meeting on Virtual Water Trade (ed. Hoekstra, A. Y.), Value of Water Research Report Series No. 12, UNESCO-IHE, Delft, The Netherlands, 2003, pp. 13–23.
5. Allan, J. A., Virtual water eliminates water wars? A case study from the Middle East. In Virtual Water Trade: Proceedings of the International Expert Meeting on Virtual Water Trade (ed. Hoekstra, A. Y.), Value of Water Research Report Series No 12, UNESCO-IHE, Delft, The Netherlands, 2003, pp. 137–145.
6. Kumar, M. D. and Singh, O. P., Virtual water in global food and water policy making: Is there a need for rethinking? *Water Resour. Manage.*, 2005, **19**, 759–789.
7. Chapagain, A. K., Hoekstra, A. Y. and Savenije, H. G., Water saving through international trade of agricultural products. *Hydrol. Earth Syst. Sci. Discuss.*, 2005, **2**, 2219–2251.
8. Horlemann, L. and Neubert, S., Virtual water trade**:** A realistic concept for resolving the water crisis? Dt. Institut für Entwicklungspolitik, Bonn, 2007.
9. Hofwegen, Paul van, Virtual water trade – Conscious choices. Synthesis E-mail Conference on Virtual Water Trade and Geopolitics, World Water Council, 2003.
10. Chapagain, A. K. and Hoekstra, A. Y., Water footprints of nations. Value of Water Research Report Series No. 16, UNESCO-IHE, Delft, The Netherlands, 2004.
11. Hoekstra, A. Y. and Hung, P. Q., Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade. Value of Water Research Report Series No. 11, UNESCO-IHE, Delft, The Netherlands, 2002.
12. Renault, D., Value of virtual water in food: Principles and virtues. In Virtual Water Trade: Proceedings of the International Expert Meeting on Virtual Water Trade (ed. Hoekstra, A. Y.), Value of Water Research Report Series No 12, UNESCO-IHE, Delft, The Netherlands, 2003, pp. 77–91.
13. Oki, T., Sato, M., Kawamura, A., Miyake, M., Kanae, S. and Musiake, K., Virtual water trade to Japan and in the world. In Virtual Water Trade: Proceedings of the International Expert Meeting on Virtual Water Trade (ed. Hoekstra, A. Y.), Value of Water Research Report Series No 12, UNESCO-IHE, Delft, The Netherlands, 2003, pp. 221–235.
14. de Fraiture, C., Cai, X., Amarasinghe, U., Rosegrant, M. and Molden, D., Does international cereal trade save water? The impact of virtual water trade on global water use. Comprehensive Assessment Research Report 4, International Water Management Institute, Colombo, 2004.
15. Zimmer, D. and Renault, D., Virtual water in food production and global trade: Review of methodological issues and preliminary results. In Virtual Water Trade: Proceedings of the International Expert Meeting on Virtual Water Trade (ed. Hoekstra, A. Y.), Value of Water Research Report Series No. 12, UNESCO-IHE, Delft, The Netherlands, 2003, pp. 93–109.
16. Chapagain, A. K., Hoekstra, A. Y., Savenije, H. H. G. and Gautam, R., The water footprint of cotton consumption. Value of Water Research Report Series No. 18, UNESCO-IHE, The Netherlands, 2005.
17. AsiaWaterBusiness, India: Time to promote virtual water measures, 2006; www.asiawateronline.com.
18. Kumar, R., Singh, R. D. and Sharma, K. D., Water resources of India. *Curr. Sci.*, 2005, **89**, 794–811.
19. Gupta, S. K. and Deshpande, R. D., Water for India in 2050: First-order assessment of available options. *Curr. Sci.*, 2004, **86**, 1216–1224.
20. Task force on HRD in IT. Department of Information Technology, 2005; http://www.mit.gov.in/eiel/bpooutsourcing.asp/ (accessed on 6 December 2005).
21. BPO India – knowledge base, 2005; http://www.bpoindia.org/KnowledgeBase/ (accessed on 8 December 2005).
22. Jain, S. K., Agarwal, P. K. and Singh, V. P., *Hydrology and Water Resources of India*, Springer, The Netherlands, 2007.
23. Hoekstra, A. Y. and Chapagain, A. K., Water footprints of nations: Water use by people as a function of their consumption pattern. *Water Resour. Manage.*, 2007 **21**, 35–48.

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