Available online at www.sciencedirect.com

SciVerse ScienceDirect

Current Opinion in Environmental Sustainability

Global change, wastewater and health in fast growing economies

Saravanan VS[1], Peter P Mollinga[2] and Janos J Bogardi[3]

It is well known that water and sanitation are important to address major water-related diseases. Less known is the impact of continuous exposure to poor water quality on human health in fast growing economies comprising about half of the world's population. Crucial questions persist — Does the economic success of emerging countries translate into improved water management and better human health, or pose additional risks? How does population growth, development of agriculture, industrialisation and urbanisation affect human health in poverty-stricken and undernourished regions? Though science has contributed significantly in addressing the threat from water-related diseases, solutions to these complex problems are still sought in a simple, one-dimensional 'cause-effect remedy' context. This paper calls for scientific and policy initiatives to move beyond this stage to understand the complex links between water and health. In addition, it urges the international community to establish a scientific monitoring and research platform to spearhead the efforts and spread information on improving water quality and human health.

Addresses
[1] Center for Development Research (ZEF), University of Bonn, Walter Flex Strasse 3, Bonn 53113, Germany
[2] SOAS, University of London, Thornhaugh Street, Russell Square, London WC1H 0XG, United Kingdom
[3] Global Water Systems Project (GWSP), Walter Flex Strasse 3, Bonn 53113, Germany

Corresponding author: Bogardi, Janos J (jbogardi@uni-bonn.de)

Current Opinion in Environmental Sustainability 2011, **3**:461–466

This review comes from the a themed issue on
Aquatic and marine systems
Edited by Lucilla Spini, Zafar Adeel and Mark W Rosenberg

Received 16 May 2011; Accepted 25 October 2011
Available online 21st November 2011

1877-3435/$ – see front matter

DOI 10.1016/j.cosust.2011.10.009

Introduction

The United Nations Development Programme World Human Development Report 2006 recognises that 'water and sanitation are the most powerful preventive medicines available to governments to reduce the rate of infectious diseases' [1]. Investment in this area is like 'immunisation to measles — a life saver' [1]. This move towards a preventive approach from a curative one received national and international attention in the past. Worldwide development agencies invested a lot in this 'powerful medicine' to combat the spread of water-transmitted diseases to achieve the Millennium Development Goals (refer Goals 4, 6 and 7). For instance, the World Bank invested $US 5.5 billion in rural water and sanitation programmes during 1978–2003 using both single sector and multisector investment instruments [2]. In spite of these efforts and investments, the incidence of water-related diseases remains high.

Global change will constrain our ability to achieve the Millennium Development Goals and will have further ramifications on water, the ecosystem and human health. Global change is frequently characterised by some pronounced features: population growth, urbanisation and related land use change, intensification of agriculture, rapid industrialisation aggravated by climate change. The consequences of this global change especially in fast growing economies are among the problems that need immediate attention. Fast growing economies are defined in this context as jurisdictional entities (countries, regions, urban agglomerations, etc.) where the trend of economic growth exceeds the global average by a considerable (over twofold or more) margin. The Earth System Science Partnerships (ESSP) state that while the 20th Century witnessed physical expansion of cities around the world, the current (21st) century is witnessing rapid growth and transformation of rural villages to city dimensions — peri-urbanisation [3••]. Peri-urbanisation describes semi-urban environments as transitions between urban centres and their surrounding, as well as the rapid development of rural settlements. A peri-urban environment may be, but not necessarily, identical to slums. When residential and economic land uses are extended to previously rural areas, the emergence and spread of water-related diseases are facilitated, biodiversity is threatened, water use is increased and traditional adaptation and mitigation measures are lost [3••]. While there is a growing concern for adequate provision of water supply and sanitation in many of these economies, there is equal concern over addressing wastewater problems generated by peri-urbanisation, which often is ignored by national and international agencies. The term 'wastewater' is used to characterise different qualities, ranging from raw to diluted sewage generated from various urban activities [4]. These activities range from domestic, commercial, industrial, stormwater and urban run-off, treated wastewater, reclaimed wastewater, faecal sludge and biosolids. These have contributed to widespread ecological and health problems in and around cities. These health hazards are not necessarily in poor quality drinking water but the daily exposure to polluted water and sewage (skin contact, inhalation and indirect consumption). Scientific research has played a significant role in offering curative

approaches, but most of the recommendations remain one-dimensional to find solutions to those diseases hyped by international agencies (like potable water supply and hygiene practices to address diarrhoea, mosquito nets to address malaria). With widespread undernourished population, filthy environment and socio-cultural factors in the developing world, it is important that science goes beyond this stage to examine the linkages among the compounding of pollutants, their quantity and the physiological impact on human health. While national and international policies remained piecemeal in addressing conventional water supply and sanitation issues, they are inadequate to effectively dispose waste waters in fast growing economies and pose high risk to public health [5••,6•].

Wastewater everywhere — living in a polluted environment

Nearly half the world's population now lives in urban settlements [7]. It is expected that in the coming decades, the population in urban areas is expected to increase from 3.4 billion in 2009 to 6.3 billion in 2050 absorbing the existing and growing urban population and drawing on some rural population. The urbanisation coupled with globalisation has led to fairly consistent higher economic growth rates since the 1990s and increase in the overall levels of national income. There has been an increase in industrial investment with expanded growth of new economic sectors. Most of this growth was in the cities and towns of less developed regions. Asia in particular is expected to have 1.7 billion, Africa 0.8 billion, and Latin America and the Caribbean 0.2 billion additional city dwellers. As the cities grow, so does their slum population. The UN-Habitat reports [8] that 31 per cent of the total urban population in the world and 41 per cent in the developing world lives in slums. Rapid population growth is a critical link to the stresses on and depletion of the environmental resources in the developing world [9]. These burgeoning patterns of growth not only created a major challenge for meeting the growing demand for water supply, sanitation and food, but also increased the call for disposing of proportional wastewater that affects urban and peri-urban regions and contributes to the widespread ecological problems in and around cities.

The most disturbing among the looming health risks is the growing menace of wastewater in urban, peri-urban and rural agriculture [5••]. Wastewater from these economies combines both domestic and industrial waste, the latter often contributing toxic pollutants that have serious direct health risks. Closing water cycles by treating and recycling industrial water is urgently needed to prevent the negative health consequences of economic growth. Instead, the increasing disposal of wastewater into water bodies and reuse in agriculture can be observed. A rough estimate indicates that at least 20 million hectares in 50 countries are irrigated with raw or only partially treated wastewater [10]. The UNDP report [1] claims, that in Latin America only 14 per cent of domestic wastewater receives any form of treatment. China with a strong record of expanding access to water is generating large quantities of domestic and industrial wastewater. Nationwide less than 20 per cent of municipal waste receives any treatment, forcing households to boil water before drinking it. In Pakistan, more than 40 per cent of water supplied, is unfiltered and 60 per cent of sewage effluents remains untreated. In the first half of 2006, major outbreaks of waterborne epidemics swept Faisalabad, Lahore, Karachi and Peshawar as a result of leakage of sewage and industrial waste into drinking water through damaged pipes. In India, with more than 50 per cent of the urban population are living as squatters; only about 35 per cent of the wastewater from big cities is treated, posing potential health risks to human population [11]. Unfortunately many of the cities in fast growing economies, like India, fail to meet the cost of safe drinking water supply and treatment of wastewater [12].

For urban and peri-urban agricultural users in fast growing economies, the untreated wastewater assumes great significance due to its year-round availability and is less expensive for the suppliers of for fresh produce to the lucrative and large urban market. Angelakis *et al.* [13] present the status of wastewater reuse in the Mediterranean countries. In Latin America, Mexico is an example where wastewater from cities and towns is extensively used to irrigate about 200,000–250,000 ha [14]. Buechler *et al.* [15] refer to assessments in few other nations like India, Pakistan, Vietnam, China, and Jordan. In China, wastewater irrigates about 1.3 million hectares of land. In Pakistan, farmers irrigating with wastewater earned between $US 300–600 per year more than their counterparts who did not use wastewater. In Kumasi, Ghana, farmers earned about 2–4 times more than their counterparts who were using non-wastewater for irrigation. Though a comprehensive worldwide assessment is the need of the hour, these studies reveal that a large area under wastewater irrigation ensures profitable returns compared to agriculturists using 'normal' water for irrigation in urban and peri-urban regions. There are a number of reasons for wastewater being an asset to the agricultural community. Apart from its year round availability, the reduced need to use fertilisers/pesticides and the ability to generate income can be mentioned [13,15].

While wastewater is a 'wealth' for the agricultural economy [16] it has serious adverse implications for human health [5••]. A particular concern is the risk to human health from the exposure to high levels of faecal coli from bacteria, worm eggs and trace organic compounds [17,18]. Interestingly these health risks vary depending on the different forms of exposure that diverse social groups face. Buechler *et al.* [15] report fevers, diarrhoea and sores on the hands and legs of farmers

and labourers exposed to wastewater. They also reveal its impact on agricultural produce. The cause of the 1970 cholera epidemic in Jerusalem and typhoid epidemics in Santiago [19] and in 1987 in Dakar [20] were all associated with raw vegetables produced in urban and peri-urban agricultural areas. As Buechler [21] points out, health risks also vary according to gender, class and ethnicity. Children of farmers or farm workers, who do not have a built up immunity, tend to be most at risk to gastrointestinal problems. In terms of environmental impact, the use of wastewater, especially from industrial sources, over a long period of time can result in heavy metal accumulation. Irrigation with industrial wastewater has been associated with a 36 per cent increase in enlarged livers and 100 per cent increases in both cancer and congenital malformation rates in China, compared to controlled areas where industrial waste water was not used for irrigation [[22 cited in 23]]. Field visits in India by one of the authors revealed adverse health effects due to wastewater. People first get skin diseases when regularly exposed to wastewater. Unfortunately for some, this skin disease transforms into chronic and severe skin infections due to diabetes which weakens health over a period of time, sometimes leading to death. Similar is the case when undernourished people are exposed to filthy wastewater, exacerbated by poorly ventilated housing and substandard work atmosphere. They are prone to tuberculosis leading to early death. The effects of unhygienic environmental and physiological factors have not been adequately examined by scientific communities in fast growing economies.

The long-term use of wastewater can become self-limiting due to soil damage. Although the organic matter in wastewater can improve soil texture and water-holding capacity, it has harmful effects, particularly in arid environments by causing soil salinisation, blocking soil interstices with oil and grease and accumulating heavy metals. In Pakistan, over-use of wastewater with insufficient drainage (also the case with freshwater irrigation) has produced signs of degradation of the soil structure, visible soil salinity and delayed emergence of wheat and sorghum due to excess nutrients.

In recent years industries have been emerging as major water users and polluters in fast growing economies. In China between 1980 and 2002, water use in industry increased from 46 to 114 billion cubic metres, an increase of 250 per cent in two decades [24]. Increasing water use proportionately augments wastewater discharge because closing of the industrial water cycles is seldom practiced in emerging economies. Some industries can be identified as heavy polluters. Of the total industrial discharge, six sectors (pulp/paper, food, chemicals, textiles, tanning and mining) accounted for 87 per cent of the total industrial chemical oxygen demand load but only 27 per cent of the gross industrial output value. In India, iron and steel industries are the highest water polluters both in terms of pollution load and toxicity [25]. In terms of pollution load, leather industries (that officially report) come second. Although data is scarce, in Pakistan industrial pollution is increasing at a rapid pace and having a significant impact on human health and productivity [26]. Most of the industries in Pakistan are located around major cities and are increasingly polluting streams, rivers and the Arabian Sea with untreated toxic waste.

Fast growing economies create the basis of future development and potential improvement. However, it does not come without substantial ecological and human health consequences. Pollution is not only increasing but is quite widespread and scattered. Small-scale industries characterise the take-off process of these economies. In Ghana, these industries provided 70 per cent of the total employment in urban centres in 1983. In China they accounted for 42 per cent of the total national industrial output in 1994 [27].

In India these industrial units account for 40 per cent of the industrial production, 35 per cent of the total exports and employ almost 17 million people in 3.2 million [28]. In Pakistan, textile industries contribute 67 per cent of the export earnings and engage 35 per cent of the labour force while the leather industry is the second largest export earning sector [29]. The situation is not different in Bangladesh. Efforts were made to treat the industrial discharge and regulate these industries but it often failed.

Box 1 Tanneries: threats at all scales.

Tanneries are selected to illustrate the links between water pollution and its influence on human health.

The tanneries use about 30–50 m^3 of water for processing a ton of hide/skin. Water is needed to process raw leather with various chemicals such as lime, sodium carbonate, sodium bi-carbonate, common salt, sodium sulphate, chrome sulphate, fat liquors, vegetable oils and dyes. Because of the water intensive nature of this process, these industries are clustered along rivers and discharge toxic pollutants. Tannery waste has strong colour (reddish to dull brown), high biological oxygen demand, high pH and high dissolved solids.

These pollutants have a devastating impact on the ecosystem and subsequently on human health. Mondal and others [31] reveal an increase in total dissolved solids (TDS) in groundwater due to disposal of untreated wastewater from tanneries. Abnormal concentration of chlorine (25–10,390 mg/l) was found in shallow groundwater due to use of sodium chloride in the tanneries. Zhang and Zhang [32] reveal the potential health hazards of ammonium, nitrogen and germanium pollutants in the Aojing watershed of China. Nitrogen in drinking water can cause the blue baby syndrome [33], reduce ecological biodiversities [34] and reduce blood oxygen transfer that can eventually destroy the tissues of the respiratory system [35,36]. Intake of high concentrations of germanium — 0.015–0.033 mg/m^3 — can cause nose bleeding, voice loss, shrinkage of nose membranes and even lung cancer [37]. These studies have identified the risks, though there is no clarity on how much tannery effluent was mixed with other biological and chemical pollutants in other wastewater. This makes it difficult to clearly identify the source of pollutants.

The 'end-of-pipe' treatment approach, poor enforcement of environment protection rules and the informal nature of these industries makesregulation difficult. A number of civil society movements and public interest litigations were filed by victims but they remain futile. 'Resistance from these enterprises is very high. Local political support is very weak. And there is not much interest in this problem in the West' [28] (Box 1).

There have been a number of initiatives to address the growing problems. National and international agencies and a number of non-governmental organisations have accelerated their efforts to meet the Millennium Development Goal 7, Target 10 (access to safe water and basic sanitation) by 2015. The WHO/UNICEF Joint Monitoring Programme confirms that despite this progress, achieving the MDG is a basic challenge [30]. The trend has been mere development of infrastructure (in this case, construction of toilets and providing pipes and hand pumps to homes). The GLAAS [6•] reports that reduced investment, inadequate policies and unclear roles and responsibilities of the different institutions involved have been major hurdles. One of the major drawbacks is the poor public health infrastructure in these countries that fails to address health service problems adequately.

Conclusions and recommendations

The unprecedented urban development in today's fast growing economies has resulted in the repetition of mistakes made during the Industrial Revolution in the so-called developed countries. What differs is the scale and rate of it and no one can claim ignorance about the apparent and potential consequences.

The alarming pollution across developing countries have been recognised by national governments, industries and non-government organisations that have been making efforts to address the problem of water quality. China has been making significant effort to address the growing crisis since the United Nations Conference on Environment and Development in 1992 through the China Water Agenda 21 (refer to [38] and to [39]) — controlling floods, restoring forested watersheds and improving water supply and wastewater treatment. However, demand management strategies, effective water pricing, conservation policies, and better institutional coordination for integrated water management were lacking [24]. India has been a pioneer in making various regulations since 1985 through a river cleaning programme, treatment of sewage and industrial pollution. However, its effectiveness is seriously being questioned. These examples — notwithstanding the massive water quality improvement programmes which became inevitable and have been implemented in the industrialised countries since the 1970s — are still 'lessons not learnt'. The lure of quick profits and anticipated competition fuels trends with inevitable negative consequences for human health — a clearly inhuman and unsustainable practice. It is important to break the vicious cycle of linking wealth creation with waste production. Because of the inertia in both governance and socio-ecological systems improvements cannot be expected swiftly. Hence early action and prevention are essential.

There is growing evidence that the undernourished section of the population is particularly vulnerable to water-related diseases [40•]. Undernutrition has been a major underlying cause of 53 per cent of the all deaths in children below the age of five years worldwide [41••]. Currently about 115 million children are underweight and 186 million under age five are stunted. The increase in diet deficiency and related long-term — actually lifelong — health effects that impair physical and mental capacities have to be taken into account. The rough estimate is that two billion people suffer from micronutrient deficiencies. Many of them are in these fast growing economies.

Water and health are closely interlinked and complex. In this complexity, one-direction interventions based on the 'cause-effect-remedy' paradigms such as providing drinking water, using toilets and washing hands becomes irrelevant to address diarrhoea when people continuously bath, inhale, work and live in and around polluted water. It is high time that (as McMichael sums up by emphasising in his conversation with Shetty [42]) science (natural, social, and medical sciences) is 'attuned to simple high-school models of science with clear-cut cause-effect relationship ... most of us are yet to grasp the risks to human societies and health from these escalating changes ...' It is important that the scientific community and policy makers move beyond this one-dimensional 'case-effect-remedy' towards a comprehensive understanding of the issues and develop integrated policy options. This requires:

1. Understanding the specific role of water quality and its impact (through direct exposure, consumption inhalation, ingestion, and skin contact) on human health.
2. Examining the compounding of pollutants and physiological confounders on human health that aggravates water-related diseases.
3. Developing effective water supply systems and disposing wastewater without harming human environment.
4. Enforcing penalties based on the polluter pays principle to finance wastewater collection and treatment facilities, recycling and water saving technologies.
5. Improving civic sense through 'anti-filth' campaigns for 'pure air, clean water and nutritious food' as key elements to healthy life.

This paper highlights the 'tip of an iceberg'. Potentially undetected health risks are still around. We should

prepare for them rather than ignore the obvious syndromes. The health-water nexus should be taken up by an international monitoring and research platform involving scientists from countries with emerging economies. Science alone, while it could spearhead the process, will not be sufficient. Solutions can be conceived but they should be approved by the relevant government bodies, implemented by city administrations and technical services and accepted by the affected people. Regional, national and local platforms would also be required. They should become active beyond the classical responsibilities of science. Dialogues with elected representatives, urban service providers, educators and the media are effective means of dissemination of scientific principles and findings. Among the water challenges of the 21st century the water quality-health nexus is certainly one of the most serious ones. Emerging economies are certainly showing signs of increasing risks and they should muster the financial and technical capacities needed to rectify the situation before it undermines global sustainability.

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. UNDP: *Human Development Report 2006 — Beyond Scarcity: Power, Poverty and the Global Water Crisis*. New York: Palgrave Macmillan, United Nations Development Programme; 2006.

2. Iyer P, Davis J, Yavuz E, Evans B: *Rural Water Supply, Sanitation, and Hygiene: A Review of 25 Years of World Bank Lending (1978–2003)*. 2006:. Water Supply and Sanitation Working Notes No. 10.

3. •• Confaloneri U, McMichael A: *Science Plan and Implementation Strategy: ESSP Joint Project on GEC and Human Health — Contribution of IHDP Task Force*. International Human Dimensions Programme (IHDP); 2007.

A very good overview of health issues in the context of global environmental change. It also sets agenda for research and policy making.

4. Jimenez B, Drechsel P, Kone D, Bahri A, Raschid-Sally L, Qadir M: **Wastewater sludge and excreta use in developing countries**. In *Wastewater Irrigation and Health Assessing and Mitigating Risk in Low-income Countries.* Edited by Drechsel P, Scott Christopher A, Raschid-Sally L, Redwood M, Akiça Bahri. Earthscan; 2010:3-28.

5. •• Drechsel P, Scott Christopher A, Raschid-Sally L, Redwood M, Bahri A: *Wastewater Irrigation and Health Assessing and Mitigating Risk in Low-Income Countries*. Earthscan; 2009.

It offers a comprehensive review and case studies on the relation wastewater irrigation and human health. It also synthesises past works from the authors who come from various disciplines. The concepts are defined and illustrated with case studies in various developing world. A good piece to get various articles in a single book.

6. • *GLAAS: UN-Water Global Annual Assessment of Sanitation and Drinking-Water-Targeting Resources for Better Results*. UN-Water and World Health Organization; 2010.

It offers a good assessment of drinking water supply and sanitation. However, it is restricted to those sectors and not beyond.

7. *United Nations: World Urbanization Prospects — The 2009 Revision Highlights*. Economic and Social Affairs; 2010.

8. *UN-HABITAT: State of the World's Cities 2006/7. The Millennium Development Goals and Urban Sustainability: 30 Years of Shaping the Habitat Agenda*. Earthscan, United Nations Human Settlements Programme; 2006.

9. Adeel Z, Piracha A. Critical links between environment and development in South Asia. In *South Asia in the World: Problem Solving Perspectives on Security, Sustainable Development, and Good Governance*. Edited by Thakur R, Wiggen O. United Nations University Press; 2004.

10. Hussain I, Raschid L, Hanjra MA, Marikar F, Van der Hoek W: *A Framework for Analyzing Socioeconomic Health and Environmental Impacts of Wastewater Use in Agriculture in Developing Countries*. International Water Management Institute (IWMI); 2002:. Working Paper No. 26.

11. Bhardwaj RM: **Water quality monitoring in India — achievements and constraints**. *IWG-Env., International Work Session on Water Statistics*; *Vienna, June 20–22, 2005: Central Pollution Control Board; 2005*.

12. Narain S: **Making water excreta accounts**.**Down To Earth**. 2009: http://www.downtoearth.org.in/fullprint.asp (accessed 25.11.09).

13. Angelakis AN, Marecos Do Monte MHF, Bontoux L, Asano T: **The Status of Wastewater Reuse Practice in The Mediterranean Basin: Need for Guidelines**. *Water Res* 1999, **33**:2201-2217.

14. Scott CA, Zarazua JA, Levine G: *Urban-Wastewater Reuse for Crop Production in the Water-Short Guanajuato River Basin*. International Water Management Institute (IWMI); 2000:. Mexico IWMI Research Report 41.

15. Buechler S, Devi G, Keraita B: **Wastewater use for urban and peri-urban agriculture**. In *Cities Farming for the Future: Urban Agriculture for Green and Productive Cities.* Edited by Van Veenhuizen R. Resource Centre for Urban Agriculture and Food Security (RUAF)/International Development Research Centre (IDRC) (IIRR/RUAF/IDRC); 2006:243-273.

16. Food and Agriculture Organization of the United Nations: *The Wealth of Waste: The Economics of Wastewater Use in Agriculture*. FAO; 2010.

17. Cooper RC: **Public health concerns and wastewater reuse**. *Water Sci Technol* 1991, **24**:55-65.

18. Ensink JHJ, Simmons RW, Van der Hoek W: **Wastewater use in Pakistan: the cases of Haroonabad and Faisalabad**. In *Wastewater Use in Irrigated Agriculture Coordinating the Livelihood and Environmental Realities.* Edited by Scott CA, Faruqui NI, Raschid-Sally L. CAB International, IWMI & IDRC; 2004:91-100.

19. Fattal B, Lampert Y, Shuval H: **A fresh look at microbial guidelines for wastewater irrigation in agriculture: a risk-assessment and cost-effectiveness approach**. In *Wastewater Use in Irrigated Agriculture Coordinating the Livelihood and Environmental Realities.* Edited by Scott CA, Faruqui NI, Raschid-Sally L. CAB International, IWMI & IDRC; 2004:59-68.

20. Faruqui NI, Niang S, Redwood M: **Untreated wastewater use in market gardens: a case study of Dakar Senegal**. In *Wastewater Use in Irrigated Agriculture Coordinating the Livelihood and Environmental Realities.* Edited by Scott CA, Faruqui NI, Raschid-Sally L. CAB International, IWMI & IDRC; 2004:113-126.

21. Buechler S: **A sustainable livelihoods approach for action research on wastewater use in agriculture**. In *Wastewater Use in Irrigated Agriculture Coordinating the Livelihood and Environmental Realities.* Edited by Scott CA, Faruqui NI, Raschid-Sally L. CAB International, IWMI, IDRC; 2004:91-100.

22. Yuan Y: **Etiological study of high stomach cancer incidence among residents in wastewater-irrigated areas**. *Environ Protect Sci* 1993, **19**:70-73 (in Chinese). In World Resources Institute A Guide to the Global Environment: Environmental Change and Human Health. Oxford University Press.

23. Carr RM, Blumenthal UJ, Mara DD: **Health guidelines for the use of wastewater in agriculture: developing realistic guidelines**. In *Wastewater Use in Irrigated Agriculture Coordinating the Livelihood and Environmental Realities.* Edited by Scott CA, Faruqui NI, Raschid-Sally L. CAB International, IWMI & IDRC; 2004:41-58.

24. Shalizi Z: *Addressing China's Growing Water Shortages and Associated Social and Environmental Consequences*. Development Research Group, World Bank (WPS3895); 2006.

25. Pandey R: **Estimating Sectoral and Geographical Industrial Pollution Inventories in India: Implications for using Effluent Charge Versus Regulation**. *J Dev Stud* 2005, **41**:33-61.

26. Aftab Z, Ali CL, Khan AM, Robinson A, Irshad IA: *Industrial Policy and the Environment in Pakistan*. Industrial Policy and Environment (NC/PAK/97/018); 2000:. United Nations Industrial Development Organization (UNIDO) Report.

27. Wu C, Maurer C, Wang Y, Xue S, Davis DL: **Water Pollution and Human Health in China**. *Environ Health Perspect* 1999, **107**:251-256.

28. Agarwal A: *Dilemma in the Developing World — Small Scale Industries Drive India's Economy, but Pollute Heavily: What Can Be Done?* Stockholm Water Institute; 2001:. Water Front, December, pp. 10–11.

29. ACU: *Annual Report-2005*. Asian Clearing Union; 2006:. 90 pp..

30. World Health Organization: *UNICEF: Progress on Sanitation and Drinking-water — 2010 Update*. WHO Press; 2010.

31. Mondal NC, Saxena VK, Singh VS: **Assessment of groundwater pollution due to tanneries in and around Dindigul, Tamil Nadu, India**. *Environ Geol* 2005, **48**:149-157.

32. Zhang M, Zhang M: **Assessing the Impact of Leather Industry to Water Quality in the Aojing Watershed in Shejiang Province, China**. *Environ Monit Assess* 2006, **115**:321-333.

33. Skipton S, Hay D: *Drinking Water: Nitrate and Methemoglobinemia (''Blue Baby'' Syndrome), Publication G98-1369*. University of Nebraska Cooperative Extension; 1998:. www.ianr.unl.edu/pubs/water/g1369.htm (accessed February 2009).

34. Radwan M, Willem P, El-Sadek A, Berlamont J: **Modelling of dissolved oxygen and biochemical oxygen demand in river water using a detailed and a simplified model**. *Int J River Basin Manage* 2003, **1**:97-103.

35. Cooke R, Kalita P: *Flow and Transport in Shallow Subsurface Drainage Systems*. University of Illinois; 2002:. available at http://www.wq.uiuc.edu/shallow/Nitrate.htm (accessed December 2007).

36. *Hubei Keliang BEC (Biological Engineering Company): Information Center, April of 2003*. Available at http://www.kernbio.com/ie/shuichan/scyz005.htm (cited in Zhang and Zhang, 2006); 2003.

37. Wang XC, Ding ZW: *Analyses and Evaluations of Leather and Raw Leather Materials and the Cleaning Production*. China: Chemical Industry Publisher Beijing; 2002:. Cited in [15].

38. People's Republic of China (PRC), Ministry of Water Resources: *China Country Report on Sustainable Development — Water Resources*. 2003.

39. World Bank: China: *Air, Land, and Water*. Environmental Priorities for a New Millennium. World Bank Report; 2001.

40. • Saravanan VS, Mollinga PP. *Environment and Human Health: An Agenda for Research*. Center for Development Research (ZEF), ZEF Working Paper 82

It offers a good overview of water and health issues from various dimensions. Most so highlights the importance of understanding the linkage between water and health from various quarters.

41. •• Bryce J, Boshi-Pinto C, Shibuya K, Black ER: **WHO Estimates of the Causes of Death in Children**. *Lancet* 2005, **365**: 1147-1152.

Highlights the crucial link between nutrition and health.

42. Shetty P: **Profile Tony McMichael: a visionary of the environment-health interface**. *Lancet* 2006, **368**:.