Wastewater management in Kunming, China: a stakeholder perspective on measures at the source

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ABSTRACT Large sewer systems with central wastewater treatment plants were long considered a successful model that could be exported to practically any city of the world. This centralized, highly water-consuming system has, however, shown its limits in some developing and transition countries, especially in fast-growing cities with limited water resources. This study from around Lake Dianchi in Yunnan, China, investigated the feasibility of introducing measures at the source for the different urban wastewater contributions in the city of Kunming, and the stakeholder perspectives on this approach. In addition, the stakeholders evaluated the potential of two different sanitation alternatives that allowed the separation and re-use of human excreta as fertilizer. Most of those interviewed approved of measures at the source, especially for industrial wastewater and toilet waste. There was a prevailing optimism with respect to the potential of technical developments and the likelihood of increased environmental awareness within a relatively short time span of 20 years. The findings suggest that China will prove to be one of the most interesting and productive "laboratories" for the development of decentralized wastewater treatment alternatives.

KEYWORDS China / ecological sanitation / expert interviews / socioeconomic / source control / stakeholders / urine separation / wastewater

I. INTRODUCTION

The provision of water and sanitation is one of the oldest and most fundamental ecological challenges of urbanization. Both human health and environmental quality are at stake and large amounts of such valuable resources as water and nutrients are involved.

Historically, Europe has relied on sewer systems with centralized wastewater treatment plants optimized for water pollution control. For a long time, it was generally accepted that this successful model could be exported to any area of the world, at least in an urban context, given the investment of sufficient means. The flush toilet became a symbol of comfort and cleanliness, and in many cases the complexity of a sewer system with centralized wastewater treatment was overlooked.

It is now generally recognized that under certain circumstances, this strategy leads to failure. In rapidly growing cities with a lack of water resources relative to population density and a chronic shortage of capital, a centralized sewage system may not be the best choice. When cities are growing fast, it takes discipline, planning and experience to expand

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capital-intensive sewer systems and, at the same time, to ensure that sufficient treatment capacity is available. The financial resources targeted for the construction of sewer lines normally account for about 80 per cent of the total investment in centralized wastewater systems. For instance in Latin America, where a relatively large proportion of the population is connected to a sewer system, only an estimated 10 per cent of the collected sewage is treated at all, and the quality of treatment is generally low.(1) With rising population density relative to the water resources available for wastewater dilution, the task of water pollution control also becomes increasingly difficult, eventually leading to situations that can hardly be managed with existing end-of-pipe technology.(2)

Even in Europe, it is well recognized that end-of-pipe technology is not suitable for all problems connected with wastewater treatment. During the last decades, measures at the source have become an integral part of European mainstream wastewater management, and have been especially successful in the case of non-degradable detergents that were prohibited during the 1960s,(3) in the control of heavy metal emissions in industry(4) and, in some countries, in introducing a phosphate ban in detergents.(5) Wastewater in a municipal sewer system is a mixture of domestic wastewater, industrial wastewater, non-polluted rainwater and infiltration water, e.g. from rivers and small streams. In Europe, technical measures at the source are taken mainly for industrial wastewater and for non-polluted wastewater. Industrial wastewater is targeted because of toxicity and a high non-degradable organic compound content. The measures are based on on-site treatment and source separation, often leading to internal savings of water and other resources.(6) Dilution with non-polluted wastewater impairs the wastewater treatment process and leads to higher loads of untreated wastewater being discharged when it rains. The main actions taken to solve this problem are: maintenance of the sewer system to prevent infiltration of groundwater; infiltration of rainwater into the ground; or separate sewers.(7) Domestic wastewater is normally divided into black water (toilet wastewater) and grey water (the rest). In Europe, measures at the source for domestic wastewater are based purely on regulation, like the ban on non-degradable detergents and phosphates in washing powder, or regulation against the discharge of such toxic materials as paint at the household level.

It is, of course, possible to extend measures at the source for domestic wastewater beyond pure regulation. Discussions of waste design have examined the possibility of achieving favourable changes in the composition of domestic wastewater based on source separation.(8) If concentrated waste streams are separated at the source and intermediately stored or treated separately, the centralized wastewater treatment process can be optimized. The best known example of waste design is urine source separation, which has been extensively examined in the literature over recent years.(9)

In rapidly growing cities, measures at the source could be even more attractive than in the mature cities in Europe, especially if a combination of such measures could replace the centralized system in whole areas of these expanding cities, thus avoiding the need to build capital-intensive sewers. In this paper, we look at the situation in Southeast Asia, exemplified by the city of Kunming, the capital of the Chinese province of Yunnan, located north of Lake Dianchi (Figure 1).

In the 1950s, Lake Dianchi had reportedly clear water and people

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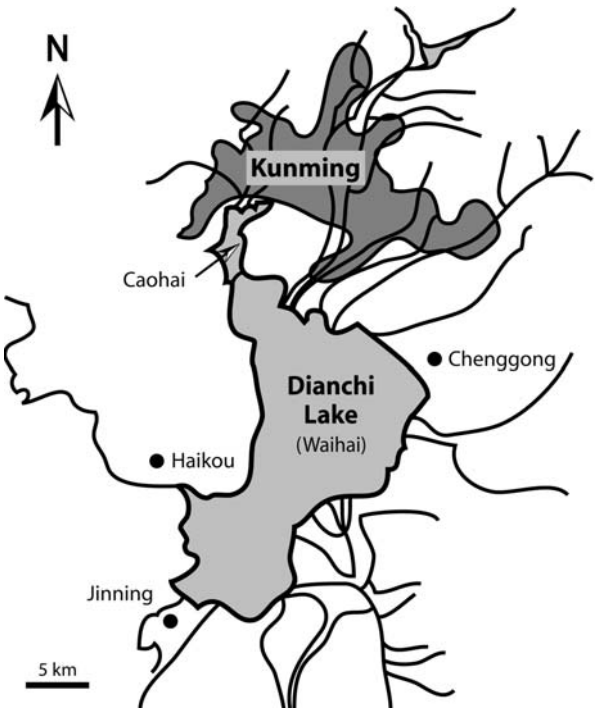

FIGURE 1
Location of the city of Kunming

SOURCE: World Bank (1996), *Environmental Assessment Report – Draft Executive Summary*, Yunnan Environmental Project Office, Yunnan Institute of Environmental Sciences in association with Montgomery Watson, GHK/MRM International, Hunting Technical Services, Severn Trent Water International, Washington DC, page 8.

swam in it, but since then, industrialization and an increased urban population have turned the lake into one of the most polluted in China.[10] The Greater Kunming Metropolitan Area is a rapidly expanding city, with a population expected to increase from today's 2.6 million to 4.5 million by 2020.[11] The lake is heavily eutrophised, with phosphorus as the limiting growth element for algae; the main origin of the phosphorus discharges into the lake is the wastewater from the city of Kunming.[12] Six modern biological wastewater treatment plants were built between 1988 and 2001, with a treatment capacity of 580,000 cubic metres of wastewater per day.[13] In a material flow analysis, however, it was shown that only about 25 per cent of the wastewater actually reached the treatment plant. Furthermore, due to the high population density and other phosphate-producing activities such as agriculture, even with the best available end-of-pipe technology the carrying capacity of the lake would still be exceeded at the current population level.[14]

The 2001 Five-Year Plan foresees additional measures at the source, most prominently a phosphate ban on detergents, and the introduction of urine source separating dry toilets in rural and peri-urban areas.[15]

1. UNEP International Environmental Technology Centre (2002), *Environmentally Sound Technology for Wastewater and Stormwater Management: An International Source Book*, IWA Publishing, London, 640 pages.

2. Huang, Don-Bing, Hans-Peter Bader, Ruth Scheidegger, Roland Schertenleib and Willi Gujer (in press), "Confronting limitations: new solutions

Since urine, faeces and detergents are the main sources of phosphorus in domestic wastewater, both measures are well suited to reducing the phosphorus load to the lake. However, measures in rural and peri-urban areas alone will not solve the complex problem of Lake Dianchi, already heavily overloaded with phosphorus.[16]

Urine source separation is found in two fundamentally different designs: the urine-diverting dry toilet (Figure 2a) and the urine-separating flush toilet (NoMix toilet, Figure 2b). These two toilet designs are intended for different situations. The NoMix toilet was developed in Sweden in the early 1990s as an alternative to the conventional flush toilet, and it closely mimics this toilet. The urine-diverting dry toilet is a hygienically improved and odourless latrine toilet. From a technical point of view, the main difference consists in the NoMix toilet being a flush toilet that still depends on water for flushing of faeces, whereas the urine-diverting dry toilet functions totally without water and any further water-borne transport and processing of faeces. This latter toilet allows for an efficient desiccation of faecal material for safer re-use as fertilizer, an important aspect in ecological sanitation. The NoMix toilet is very flexible and can be used for optimizing existing centralized wastewater treatment with or without the option of nutrient recycling.[17]

First results indicate that the NoMix toilet is relatively well accepted in Europe, although there is still scope for improvement with respect to design and technology.[18] The NoMix toilets have also been well received in a number of pilot projects in institutional settings.[19] The little evidence obtained concerning the urine-diverting dry toilet in personal

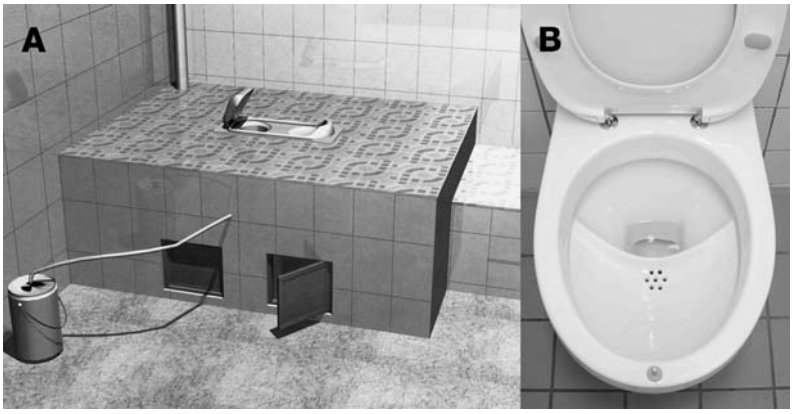

FIGURE 2
Two urine-separating sanitation alternatives

A: The urine-separating dry toilet, which functions without water

SOURCE: Courtesy of Lin Jiang, Associate Professor and member of the Guangxi Committee of the Jiu San Society, Department of Science and Technology, Nanning City.

B: The urine-separating flushing toilet (NoMix toilet)

SOURCE: Roediger Vakuum- und Haustechnik GmbH, Hanau, Germany. Training document courtesy of Lin Jiang.

required for urban water management in Kunming City", accepted for publication in *Journal of Environmental Management*.

3. Harremoës, Poul (1998), "Upgrading our inherited urban water systems", *Water Science and Technology* Vol 37, No 9, pages 1–8.

4. Scherer, Ulrike, Stephan Fuchs, Horst Behrendt and Thomas Hillenbrand (2003), "Emissions of heavy metals into river basins of Germany", *Water Science and Technology* Vol 47, No 7–8, pages 251–257.

5. Siegrist, Hansruedi and Markus Boller (1999), "Auswirkungen des Phosphatverbots in den Waschmitteln auf die Abwasserreinigung in der Schweiz", *Korrespondenz Abwasser* Vol 46, No 1, pages 57–65 (in German).

6. Christ, Claus (1999), "Integrated environmental protection reduces water pollution", *Chemical Engineering and Technology* Vol 22, No 8, pages 642–651.

7. Krejci, Vladimir (1996), "Integrated approach to the point-non point-pollution abatement in urban drainage", *Water Science and Technology* Vol 33, No 4–5, pages 9–15; also Walsh, Christopher J, Tim D Fletcher and Anthony R Ladson (2005), "Stream restoration in urban catchments through re-designing stormwater systems: looking to the catchment to save the stream", *Journal of the North American Benthological Society* Vol 24, No 3, pages 690–705.

8. Henze, Mogens (1997), "Waste design for households with respect to water, organics and nutrients", *Water Science and Technology* Vol 35, No 9, pages 113–120; also Larsen, Tove A and Willi Gujer (1997), "The concept of sustainable urban water management",

households[20] emphasizes how important it is that the toilets are used correctly and that the users are properly involved in all aspects of the implementation process.

In the study described here, we aim for an understanding of how stakeholders evaluate the potential of different measures at the source to solve the wastewater problems of Kunming, and the possibility of such measures being introduced in the future. On the one hand, we want to understand how Chinese experts generally judge the importance of measures at the source for the single wastewater sources. On the other hand, we investigate the specific attitude of these same experts towards the concept of urine source separation in an urban context, a measure already foreseen for rural and peri-urban areas in the catchment area of Lake Dianchi.

II. METHODOLOGY AND PROCESS

We relied on expert interviews to identify the attitude of the most important stakeholders towards different measures at the source for more effective wastewater treatment. Meuser and Nagel[21] define an expert as a person with a specific responsibility for the draft, implementation and control of a problem solution, as well as having privileged access to information. According to this methodology, experts represent the problem-solving capacity and decision-making structure of an organization or institution. We selected a number of stakeholders who would act as experts on the introduction of urine source separation in Kunming, and we conducted interviews with representatives of these stakeholders. Generally, we use a highly structured interview method with a large number of closed questions. However, we made important extensions to this questionnaire based on the problem-centred expert interviews described by Witzel.[22] This latter type of interview procedure is only loosely bound to a well-defined topic, giving the interviewee the opportunity to freely add qualitative information.

In another work,[23] we identified and characterized the stakeholders who might potentially play a role in the implementation of urine source separation in the city of Kunming (Table 1). We met representatives of most of these stakeholders for a one-hour interview, using structured standardized guidelines that allowed us to collect both qualitative and quantitative data. Technical fact sheets were prepared to help convey information to the stakeholder representatives during the interviews. Figure 3 illustrates the interview guidelines that were followed, and the interventions with the fact sheets at different stages of the interview to present the concept of measures at the source, also the central role of urban sanitation in the polluting of Lake Dianchi, and the two urine source separating alternatives. The interviews usually took place in Chinese and the interviewer wrote down the qualitative information answers. The quantitative answers were written down directly by the interviewees on a previously prepared form.

The interviews were structured in three parts. In Part I, the concept of applying measures at the source to improve wastewater management was introduced and discussed, and the measures at the source for five different wastewater sources were evaluated (Figure 4).

In Part II, the two urine-separating alternatives were presented (Figure 2), and the potential and limitations for urban implementation

Water Science and Technology Vol 35, No 9, pages 3–10; and Larsen, Tove A and Willi Gujer (2001), "Waste design and source control lead to flexibility in wastewater management", *Water Science and Technology* Vol 43, No 5, pages 309–317.

9. Johansson, Mats (2000), "Urine separation – closing the nutrient cycle", Stockholm Water Company, accessed 6 February 2006 at http://www.stockholmvatten.se/pdf_arkiv/english/Urinsep_eng.pdf, 40 pages; also Rauch, Wolfgang, Doris Brockmann, Irene Peters, Tove A Larsen and Willi Gujer (2003), "Combining urine separation with waste design: an analysis using a stochastic model for urine production", *Water Research* Vol 37, No 3, pages 681–689; and Wilsenach, Jac A and Mark C M van Loosdrecht (2004), "Effects of separate urine collection on advanced nutrient removal processes", *Environmental Science and Technology* Vol 38, No 4, pages 1208–1215.

10. Gray, A V and Wang Li (1999), "Case study on water quality modelling of Dianchi Lake, Yunnan Province, South-West China", *Water Science and Technology* Vol 40, No 2, pages 35–43.

11. KUPDI (2003), *Planungskonzept des Städtesystems um den Diansee – Die "vier-Zonen-um-den-See" – Plannung*, Kunming Urban Planning and Design Institute, Kunming, internal document, 34 pages (in German).

12. World Bank (1996), *Environmental Assessment Report – Draft Executive Summary*, Yunnan Environmental Project Office, Yunnan Institute of Environmental Sciences in association with Montgomery Watson, GHK/MRM International, Hunting Technical Services, Severn Trent Water International, Washington DC, page 8.

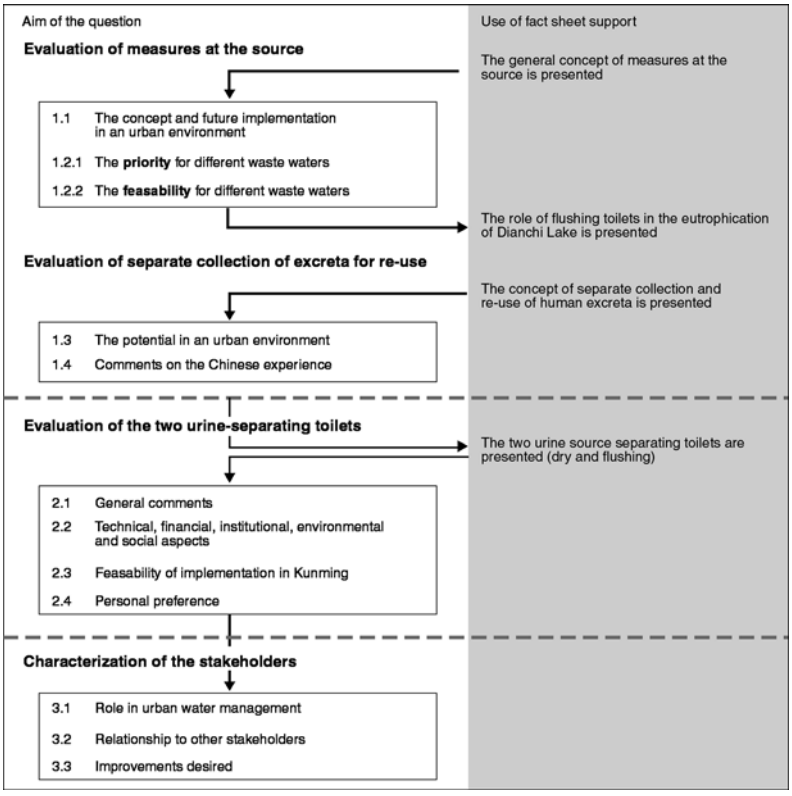

FIGURE 3
Guidelines for conducting expert interviews

The third part of the guidelines was used for a stakeholder analysis published elsewhere, and will not be further discussed in this paper.

were evaluated. Different aspects and future perspectives for these alternatives were taken into account.

In Part III, the stakeholder representatives described the activity of his or her organization and the relationship with other stakeholders. This part of the interview helped us refine the stakeholder analysis; this was presented elsewhere and is not discussed further here.[24]

In order to compare the qualitative statements of the interviewees, we treated the data as follows.[25] First, the qualitative answers were written down as they were expressed by the interviewee. The resulting text was then paraphrased without modifying the information content, in order to facilitate comparison between the interviews. The answers were then summarized with keywords or short sentences to concentrate and better visualize the information. Finally, the answers were thematically compared between the interviews and grouped according to whether the stakeholder saw a potential or a limitation for the specific aspect in question. The number of stakeholder representatives making similar statements was tallied.

13. Management Department of the Sewerage Treatment Plant at the Kunming Municipal Sewerage Corporation (2004), personal communication.

14. See reference 2.

15. Task Group (2001), *Tenth Five-Year Plan*, Task Group of Water Pollution Control in Dianchi Catchment Area, Kunming, pages 22–25 (in Chinese).

16. For a detailed mass flux analysis, see reference 2.

17. Larsen, Tove A, Irene Peters, Alfredo Alder, Rik Eggen, Max Maurer and Jane Muncke (2001), "Re-engineering the toilet for sustainable wastewater management", *Environmental Science & Technology* Vol 35, No 9, pages 192A–197A.

18. Pahl-Wostl, Claudia, Andreas Schönborn, Nicole Willi, Jane Muncke and Tove A Larsen (2003), "Investigating consumer attitudes towards the new technology of urine separation", *Water Science and Technology* Vol 48, No 1, pages 57–65; also Udert, Kai M, Tove A Larsen and Willi Gujer (2003), "Biologically induced precipitation in urine-collecting systems", *Water Science and Technology: Water Supply* Vol 3, No 3, pages 71–78.

19. Lienert, Judit, Kirsten Thiemann, Ruth Kaufmann-Hayoz and Tove A Larsen (2004), "Young users accept NoMix toilets – a questionnaire survey on urine source-separating toilets in a college in Switzerland", Proceedings of the 4th IWA World Water Congress and Exhibition, 19–24 September 2004, Marrakech, Morocco (CD-Rom); also Lienert, Judit and Tove A Larsen (2006), "Considering user attitude in early development of environmentally friendly technology: a case study of NoMix toilets", *Environmental Science & Technology* Vol 40, pages 4838–4844.

20. Bregnhøj, Henrik, Ann Marie Eilersen, Martin Krayer von Krauss and Arne Backlund (2003), "Experiences with ecosan in Danish allotment gardens and in development projects", in *Ecosan – Closing the Loop*, Proceedings of the 2nd International Symposium on Ecological Sanitation in Lübeck, 2003, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, pages 143–150.

21. Meuser, Michael and Ulrike Nagel (1991), "ExpertInneninterviews – vielfach erprobt, wenig bedacht. Ein Beitrag zur qualitativen Methodendiskussion", in Detlef Garz and Klaus Kraimer (editors), *Qualitativ-empirische Sozialforschung*, Westdeutscher Verlag, Opladen, pages 441–468 (in German).

22. Witzel, Andreas (1982), *Verfahren der qualitativen Sozialforschung. Überblick und Alternativen*, Campus, Frankfurt am Main, 136 pages (in German).

23. Medilanski, Edi, Chuan Liang, Hans-Joachim Mosler, Roland Schertenleib and Tove A Larsen (in press), "Identifying the institutional decision process to introduce decentralized sanitation in the city of Kunming (China)", accepted for publication in *Environmental Management*.

24. See reference 23.

25. See reference 21.

26. See reference 23.

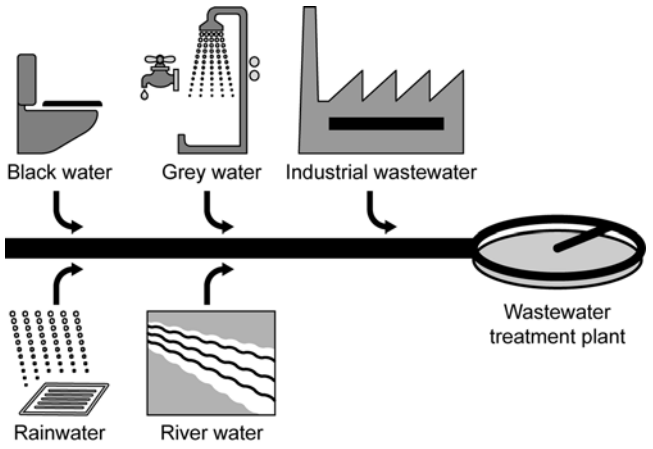

FIGURE 4
The end-of-pipe concept for wastewater management (the different wastewater sources (black water, grey water, industrial wastewater, rainwater and river water) are mixed in a sewer system and centrally treated by a wastewater treatment plant)

SOURCE: Esrey, Steven A, Jean Gough, Dave Rapaport, Ron Sawyer, Mayling Simpson-Hébert, Jorge Vargas and Uno Winblad (1998), *Ecological Sanitation*, Swedish International Development Cooperation Agency (Sida), Stockholm, page 2.

The interview guidelines and the fact sheets were initially pre-tested with five stakeholder representatives in China, in order to improve the procedure before conducting the final interviews according to the guidelines presented in Figure 3. The test interviews were then discarded and new interviews were conducted with other representatives from those five stakeholders.

III. RESULTS

a. The stakeholders

Thirty-five stakeholders were identified (Table 1), mainly government offices under the Kunming jurisdiction; also five non-governmental stakeholders (#7, #30, #31, #32, #33) and five stakeholders outside of Kunming (#13, #14, #15, #34, #35). About one-quarter of the stakeholders are research institutions. An overview of the Chinese political and administrative structure relevant to wastewater management, and the status of the stakeholders with respect to interest and decision-making powers in relation to urine source separation is available in another paper.[26]

We conducted interviews with representatives of most of the listed stakeholders. Only the Municipal Government (#1), the Municipal Public Utilities Bureau (#5) and the Municipal Law Bureau (#16) could not be reached for an interview. Double interviews were conducted with two stakeholders: Real Estate (#7) and Qinghua University (#13), resulting in a total of 34 interviews.

TABLE 1
List of identified stakeholders who could play a role in the implementation of urine source separation in the city of Kunming

#	Stakeholder
1	Municipal Government
2	Municipal Communist Party
3	Municipal Congress
4	Dianchi Lake Protection Bureau
5	Municipal Public Utilities Bureau
6	Municipal Foreign Affairs Bureau
7	Real Estate (two interviews)
8	Kunming Sewer Corporation
9	Yunnan Environmental Protection Bureau
10	Provincial Institute of Environmental Science
11	Municipal Environmental Protection Bureau
12	Kunming Institute of Environmental Science
13	Qinghua University, Beijing (two interviews)
14	Research Centre for Eco-Environmental Science
15	Chinese Academy of Agricultural Engineering
16	Municipal Law Bureau
17	Kunming Water Supply Company
18	Yunnan Academy of Social Science
19	Provincial Fertilizer Station
20	Environmental Monitoring Station of the Yunnan EPB
21	Municipal Public Health Bureau
22	Municipal Civil Construction Bureau
23	Municipal Agriculture Bureau
24	Municipal Urban Planning Administration Bureau
25	Municipal Financial Bureau
26	Dayu Township Government
27	Chenggong Environmental Protection Bureau
28	Taishi Township Government
29	County Fertilizer Station
30	Zhonghe Village (rich village)
31	Taishi Village (poor village)
32	Phosphorus Mining Company
33	Kunming University of Science and Technology
34	Tianjin Environmental Protection Bureau
35	IRL-ETHZ Sib Denx Village Rehabilitation Project

b. Part 1: evaluation of the concept of measures at the source for the city of Kunming

General evaluation of the implementation of the concept in the city. The quantitative estimates of present and potential future implementation of measures at the source in Kunming are summarized in Figure 5. The current implementation of measures at the source in the city is considered very low, with 85 per cent of stakeholder representatives considering that they are "not at all", "very little" or "little" implemented

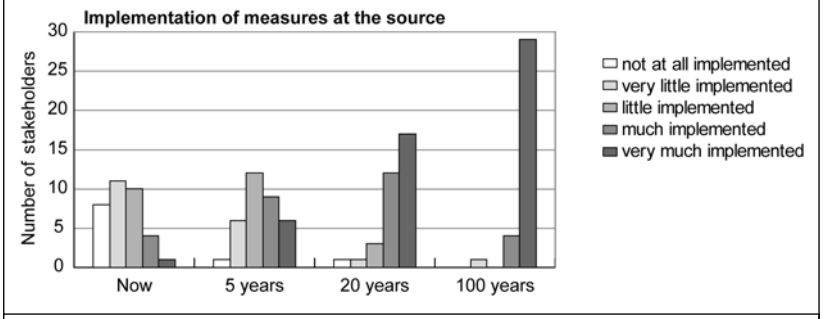

FIGURE 5
Evaluation of the general concept of measures at the source (MAS) in urban wastewater management

now. Simultaneously, 85 per cent of stakeholders anticipated that in 20 years time, these measures would be "much" or "very much" implemented.

The open interviews established that about two-thirds of the stakeholders supported measures at the source in a general way, and that only one stakeholder – the Municipal Urban Planning Administration Bureau – did not actively support the concept. Eight experts see the most important potential for measures at the source as being in new urban areas with no existing water infrastructure. A number of barriers emerged at the political, financial and technological levels and with respect to public awareness. Interestingly, the most frequently mentioned barriers were political (mentioned nine times), whereas technical barriers were the least frequently mentioned (only six times).

Detailed evaluation of five wastewater sources (priority and feasibility). The five wastewater sources that were evaluated were black water (toilet wastewater), industrial wastewater, grey water (domestic wastewater without black water), rainwater and river water. The quantitative information is summarized in Figure 6.

Black water and industrial wastewater are both perceived as the wastewater sources where measures at the source are most urgently needed, with over 90 per cent of the stakeholders ranking this priority as "high" or "very high". Specific measures for rainwater were given a "high" or "very high" priority by half of the stakeholders, whereas fewer than 30 per cent found that measures at the source for grey water and river water have the same level of priority.

Despite the high priority given to the implementation of measures at the source for toilet wastewater, the feasibility of such measures is at the moment considered very low, with only 30 per cent of the stakeholders considering present feasibility "high" or "very high". Perspectives on the situation after 20 years are, however, more promising, with feasibility improving to 85 per cent for excreta and to 74–97 per cent for the other wastewater sources.

The qualitative statements for the implementation of measures at the source on the different contributors to municipal wastewater are summarized below.

There is broad awareness of the fact that, increasingly, industry is

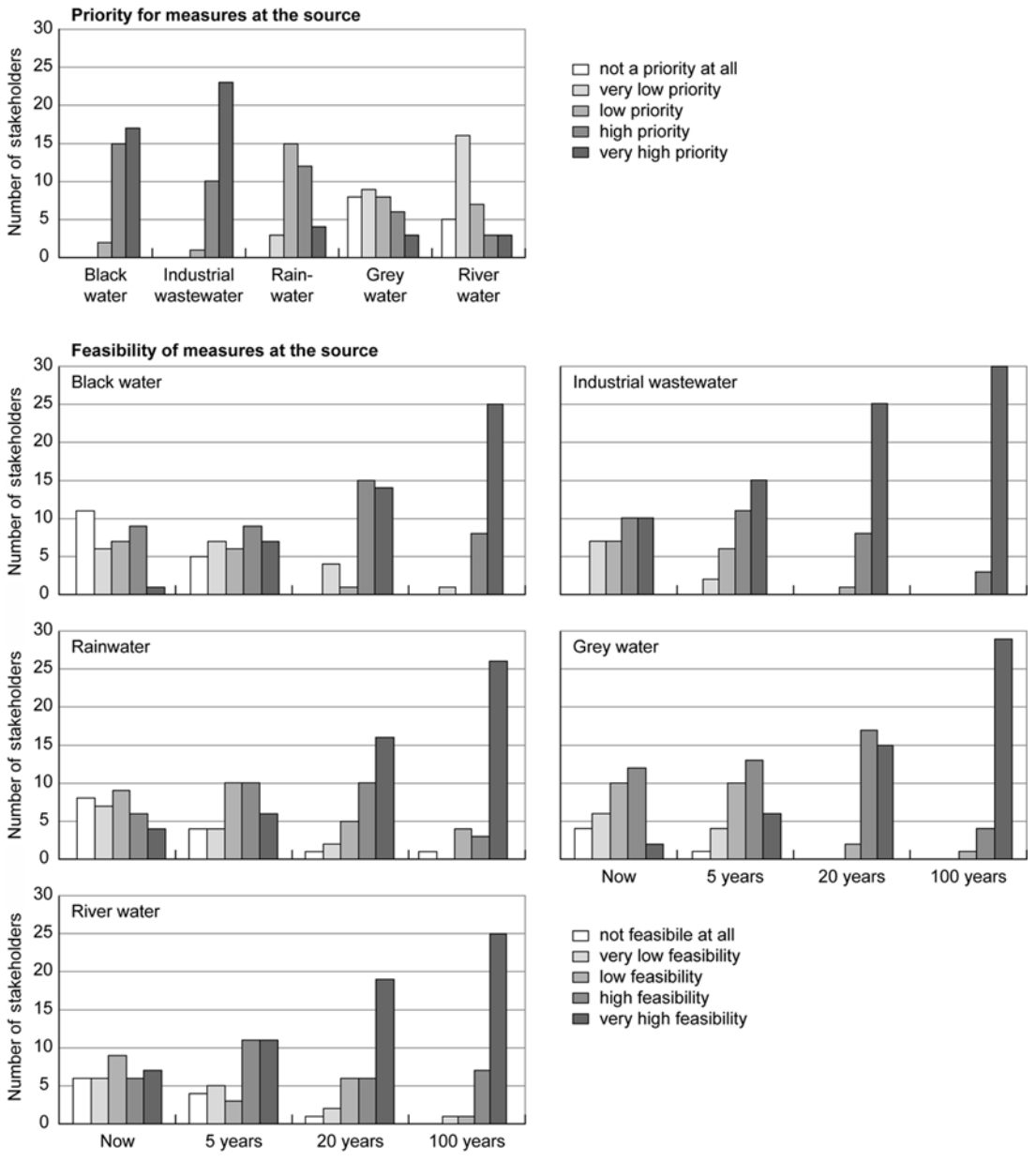

FIGURE 6
Evaluation by the stakeholders of priority and feasibility to implement measures at the source on the different contributors to wastewater

treating its own wastewater, with 20 experts mentioning this fact. Also, grey water recycling is relatively well known, with ten experts referring to it. For black water, seven experts were in favour of decentralized wastewater treatment, but technical difficulties and a lack of public acceptance were mentioned. Strikingly, Chinese stakeholders met measures at the

source to keep unpolluted rainwater and river water separate from wastewater with some scepticism. Although between one-third and one-half of the experts were aware that these measures are actually taken in Kunming, the importance of measures at the source for rainwater in particular is not recognized: 20 of the experts doubted the usefulness of such measures, which are highly favoured in Europe. Similar doubts were expressed with respect to grey water, where 13 experts found measures at the source to be not useful.

Comments on the concept of separate collection and re-use of human excreta. Following a presentation on the key contribution of flush toilets to the poor state of Lake Dianchi, a specific discussion on excreta was conducted. Nearly half of the experts saw great potential for recycling urban nutrients but household preference for the hygienic advantages of flush toilets was raised again (explicitly mentioned by nine experts).

c. Part 2: evaluation of the urine-separating alternatives

The urine-separating dry and flush toilets were presented to the stakeholders, who commented on them in general terms before specifically discussing their different aspects.

General evaluation of the sanitation alternatives. The European NoMix toilets, at a cost of about US$ 1,000 each were, of course, considered exorbitantly expensive by most of the experts (22 out of 34). A price of US$ 25–60 for a dry urine-separating toilet was much more acceptable to the experts. Ten experts mentioned lack of acceptance as a problem for NoMix toilets, and 14 experts mentioned it as a problem for the urine-diverting dry toilet. Whereas seven experts considered the NoMix toilet technology to be a problem, there were more detailed comments on the technical problems of the urine-separating dry toilet, a technology much more familiar to the stakeholders interviewed. Eleven experts commented on the unsuitability of this toilet in an urban context. The problems of providing ash, the lack of space and acceptable management were mentioned in particular. However, four interviewees from the research field who support the concept of waterless urban sanitation proposed adaptations for more acceptable dry toilets in urban areas: large collective containers could allow smaller chambers in the individual households, and a public collection service for the excreta would minimize the labour required by the family.

Specific evaluation of five aspects of the sanitation alternatives. Figure 7 shows the quantitative evaluation of the two urine source separating alternatives with respect to technical, institutional, financial, environmental and social aspects. With the more focused questions, the different perceptions of the two toilets are covered in more detail.

The technical aspects of both urine source separating alternatives were evaluated very positively, with the NoMix being considered more feasible (82 per cent evaluating this alternative as positive or very positive) than the dry toilet system (70 per cent). Institutional aspects and social acceptance in cities were perceived as clearly better for NoMix toilets (79 per cent and 53 per cent of positive votes, respectively) than for dry toilets (38 per cent and 24 per cent, respectively), and both alternatives scored very well on the environmental aspects (82 per cent for NoMix toilets and 97 per cent for dry toilets). Only the financial aspects

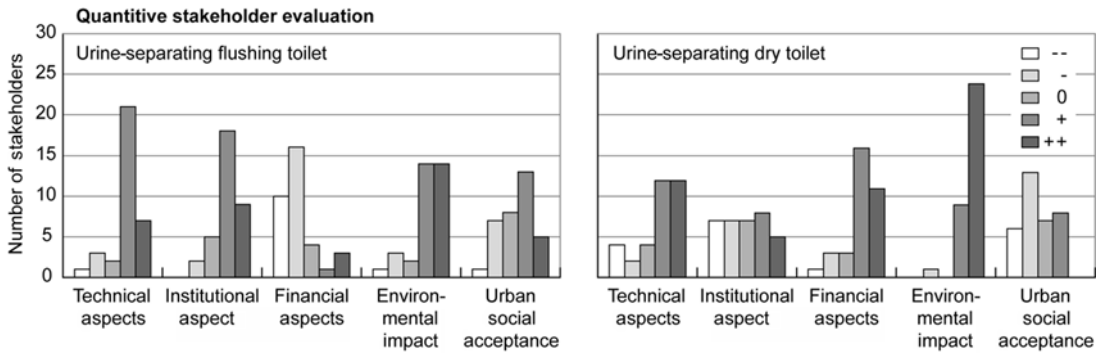

FIGURE 7
Quantitative evaluation of the two different urine-separating toilets on five different aspects. The ranking spans from very negative (– –) to very positive (++)

were considered to be strongly negative for NoMix toilets, with 12 per cent of positive votes versus 79 per cent for the dry toilet alternative.

The most noteworthy results from the qualitative statements were the remarks on technical feasibility (seen as unproblematic for both alternatives by about 18 experts), and the obvious fact that the NoMix toilets are far too expensive for the Chinese population (22 experts). A large minority felt that the management of NoMix toilets would be easy (11 experts), that dry toilets were inconvenient in an urban setting (six experts) and that the environmental impact of dry toilets is better than for NoMix toilets (eight experts). Four experts pointed out that with a purely Chinese production of NoMix toilets, the price would be much lower.

Perspectives for the implementation of the sanitation alternatives in the city. The estimated chances for present and future implementation of the sanitation alternatives are shown in Figure 8. According to this, the implementation of neither sanitation alternative is considered feasible today, with 90 per cent estimating that they can only be implemented "very little" or "not at all". Sixty per cent think that NoMix

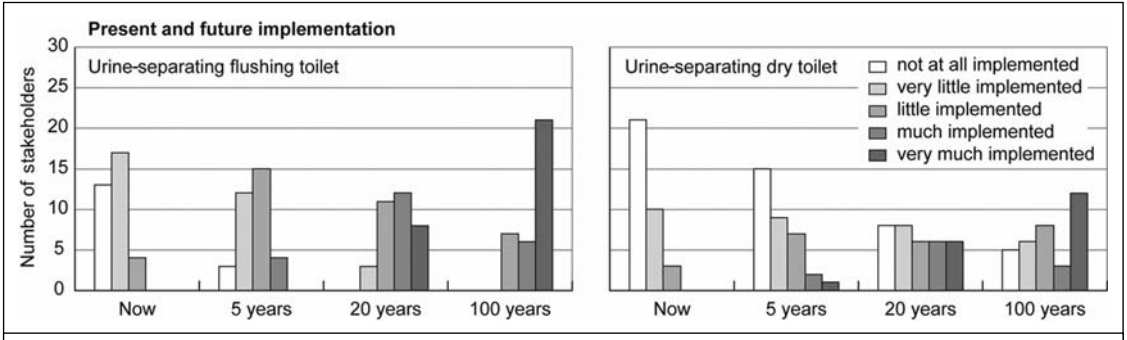

FIGURE 8
Evaluation of the present and future implementation of the two different urine-separating toilets

toilets, and only 35 per cent that dry toilets, could be "much" or "very much" implemented after 20 years. After 100 years, the figures rise to 80 per cent and 44 per cent, respectively.

Slightly fewer than half the experts (15) thought that public awareness would improve in the future. A rather large minority (13) expected the technologies to become cheaper in the future, primarily due to technological improvements. Twelve experts mentioned the unsuitability of dry toilets in an urban setting; however, seven experts thought that lack of water or improved awareness could make the dry toilets an option in an urban setting.

Preferences regarding the two sanitation alternatives. Twenty-five stakeholders out of 34 (74 per cent) preferred the NoMix toilet to the dry toilet system. One representative from the real estate company did not like either alternative, and the rest (24 per cent) favoured the urine-separating dry toilets. The main arguments are in line with the arguments given above. However, valuable suggestions for technical improvements to the urine-diverting dry toilets were given (e.g. a combination of small household storage chambers and larger ones on the level of apartment buildings, or the creation of public services for management), suggesting that locally driven innovation is possible.

IV. DISCUSSION

The stakeholders agree to a large extent that measures at the source are only little implemented in Kunming. Nevertheless, they are well known and broadly favoured among the stakeholders, albeit with a focus that in some areas differs considerably from the mainstream European attitude. Whereas the emphasis on measures at the source for industrial wastewater largely follows the European approach, the broad acceptance of measures at the source for toilet wastewater is striking. Equally striking is the fact that the importance of keeping non-polluted storm and river water out of the sewers is generally questioned in both quantitative and qualitative responses. It must, however, be mentioned that the stakeholder representing the Sewer Corporation, and therefore directly involved in wastewater handling in Kunming, shares the European view on non-polluted storm and river water (high priority and good feasibility for measures at the source) and on black water (low priority and very low feasibility for measures at the source; data not shown). We therefore conclude that the lack of interest in measures at the source for storm and river water is mainly a question of unfamiliarity, on the part of a large number of stakeholders, with the negative consequences of dilution on the effectiveness of wastewater treatment plants. In accordance with the perception in Europe, the topic of grey water was not considered of great importance.

At the moment, we can only speculate as to why measures at the source for toilet wastewater are so positively perceived. There are three possible explanations. First, the negative experience of the effectiveness of wastewater treatment plants, despite remarkable efforts and large investments in the 1990s,[27] may convey the picture that stronger support of decentralized solutions for the concentrated waste streams would be appropriate. This support was already confirmed with the Tenth Five-Year Plan recently adopted by the government of Kunming, where measures at water pollution sources complemented the wastewater

27. World Bank (2001), *China – Air, Land and Water: Environmental Priorities for a New Millennium*, The International Bank for Reconstruction and Development/The World Bank, Washington DC, page 60.

treatment enhancement and ecosystem rehabilitation plans.[28] Second, the increasing water requirements in Kunming, with its planned massive urban expansion,[29] highlight the dramatic situation of the lake and may therefore call for direct measures on all wastewater contributors. Even grey water recycling could be necessary in order to provide enough water and reduce the amount of wastewater discharged into the lake. Finally, the successful introduction of urine-diverting dry toilets in rural areas of the neighbouring province of Guangxi[30] provides positive associations with such decentralized sanitation units.

The optimism of the stakeholders with respect to technological possibilities is noteworthy. Within a relatively short time span (20 years), most of the stakeholders expect measures at the source to be widely implemented. This optimism is consistent in both parts of the interview, although it becomes less pronounced the more concretely the technological alternatives on urine source separation are presented (in Part II). The scepticism is especially pronounced for the dry toilet, which more than half of the stakeholders see as potentially only little implemented even after 100 years (as compared to only 20 per cent for the NoMix toilet). This indicates that the majority of the stakeholders are against the concept of a non-flushing toilet, whereas the NoMix concept finds much greater support. There may also be a reliance on other decentralized alternatives such as septic tanks, which are relatively common in Kunming, an option, however, that we did not pursue in the interviews. Still, we can conclude that measures at the source, combined with a western-style flush toilet, are highly favoured by the stakeholders interviewed.

Only slightly greater importance was given to political barriers than to technical barriers (nine experts mentioned political barriers versus six experts mentioning technical barriers), but even this small difference may be significant. In previous work, we found that a few key political stakeholders are presumed to be the most important barrier to introducing decentralized sanitation technologies in urban areas of Kunming. However, there is a general feeling that these key stakeholders could be influenced by successful pilot projects.[31]

The difference between rural and urban settings is well captured by the interviews in Part II. It is generally anticipated that an urban population will not accept the dry toilets, and even the acceptance of a western-style NoMix toilet is considered problematic, although the high price may have influenced unduly the answers on acceptance (i.e. it was anticipated by the interviewees that people would not accept the high price). About two-thirds of the population in the catchment area of Kunming are urban,[32] and it will thus be essential to reach the urban population with acceptable technology. Although acceptance is considered higher for the NoMix toilet, a number of stakeholders also recognize that the environmental effects of the urine-diverting dry toilet are better because it deals with the entire amount of black water, and not only with urine. In our opinion, we capture the wish for western-style flush toilets rather well with the option of the NoMix toilet, although it is obvious that more comprehensive solutions are necessary in Kunming.

If dry toilets are to be installed successfully in an urban context, the problems of management, the provision of ash and the requisite space call for innovative technical and organizational solutions. While the provision of ash or another drying material could be dealt with through

28. See reference 15.

29. See reference 11.

30. Lin, Jiang (2002), "Ecosan development in Guangxi, China", EcoSanRes Proceedings of the First International Conference on Ecological Sanitation, 5–8 November 2001, Nanning, China.

31. See reference 23.

32. *Kunming Statistical Yearbook* (2002), China Statistics Press, Kunming, China, page 37.

a good management system (which would also obviously involve a central collection system), the space issue may be more difficult to solve. It is a question of whether low-tech solutions, with their dependence on space and time-consuming processes, will ever be adequate under the space-limited conditions in large, modern cities like Kunming. However, the success experienced in rural and peri-urban areas in China obviously makes it worthwhile to invest in the further development of these systems in order to adapt them to an urban environment. The suggestions for improvement cited above show that local initiative is not lacking.

V. CONCLUSION

In rapidly growing cities like Kunming, decentralized technologies have a great potential for alleviating the problems of controlling water pollution. Through expert interviews, we found that most expert stakeholders in Kunming approved of measures at the source, especially for industrial wastewater and toilet waste. There was, however, little awareness of the negative impact of dilution by river water and/or rainwater on the effectiveness of central wastewater treatment, especially among stakeholders not directly concerned and experienced with wastewater treatment technology. Nor was the topic of grey water considered of great importance. However, the extreme situation in the catchment area of Lake Dianchi, the most important receiving water in the greater metropolitan area of Kunming, requires comprehensive solutions, probably including severe measures at the source and possibly even grey water recycling.

With respect to feasibility, the stakeholders interviewed considered today's technical solutions at the source inadequate, but there is strong and almost unanimous optimism that the technology will be significantly improved within the relatively short time span of 20 years – perhaps indicative of the fast-changing situation in China. Optimism is most notable for decentralized solutions combined with western-style flush toilets. The rapid expansion of the city is a severe handicap to the development of centralized sewer-based wastewater management, but it may constitute an excellent laboratory for the development of decentralized innovative solutions. Local initiative with respect to technical innovation is available, and most of stakeholders are open-minded.

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