SUSTAINABLE WATER MANAGEMENT IN A DESERT MEGACITY ON THE COAST: LIMA METROPOLITANA - HOW CAN EDUCATION AND CAPACITY BUILDING CONTRIBUTE TO THIS? -

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ABSTRACT

The capital of Lima, Peru, has about 8 million inhabitants. Its population is growing in a fast pace. This, together with an annual rainfall of only 9 mm and the scarcity of fresh water resources, poses particular challenges on water and wastewater management. In addition to the fact that around 20% of the population of Lima is not connected to the sewage network, the amount of adequately treated wastewater is quite low. Significant investments in wastewater management have been made recently in Lima. Nevertheless, most wastewaters collected are discharged into the receiving waters and finally the Pacific Ocean without treatment. This contribution briefly outlines the application-oriented research project "Water supply and wastewater in megacities of tomorrow - Concepts for Metropolitan Lima (Peru) and elsewhere" ("Lima Water – LiWa"), which is co-funded by the German Ministry of Education and Research BMBF. Later sections of the paper then focus on the educational aspects of the project. "LiWa" aims at identifying and addressing the most important of these pressing issues by an analysis of the situation, development of ideas and plans of adapted wastewater treatment and development and implementation of management concepts adequate for the particular boundary conditions. Partners from various disciplines from academia, the local water operator, industry and NGO sector from Peru and Germany are working together on a sustainable concept for management of Lima, taking into account its specific climate conditions. Education of local operators, authorities and citizens is crucial to assure sustainability not only during the project phase but also over the next decades.

Key words: arid climate, megacity, modelling, sustainability, urban water, wastewater, water management

1. INTRODUCTION

The capital of Lima, Peru, today has about 8 million inhabitants. Its population is growing in a fast pace (annual growth rate of 2.1%), mainly by people moving from all over the country to the capital and then settling down in periurban settlements. This, together with an annual rainfall of only 9 mm and the scarcity of fresh water resources, poses particular challenges on water and wastewater management in this emerging megacity. The city's water management situation is characterised by a typical linear concept: Water is taken from some reservoirs far from the city and is then discharged into the ocean after use. Although some reuse of water already takes place, motivated by the scarcity of water resources, yet untreated or insufficiently treated wastewater is used for irrigation of agricultural land and for watering of parks, posing significant health risks. In addition to the fact that around 20 % of the population of Lima is not connected to the sewage network, the amount of adequately treated wastewater still is quite low. Significant investments in wastewater management have been made recently in Lima. Nevertheless, most wastewaters collected are discharged into the receiving waters and finally the Pacific Ocean without adequate treatment. Therefore, the current situation still needs improvement.

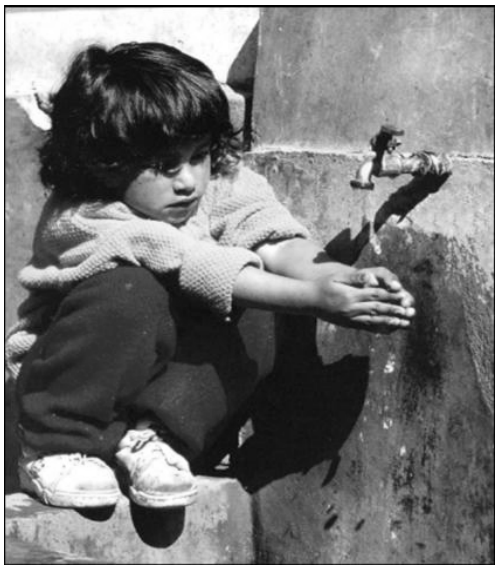

Figure 1 Each time the water resource is becoming scarcer in Lima

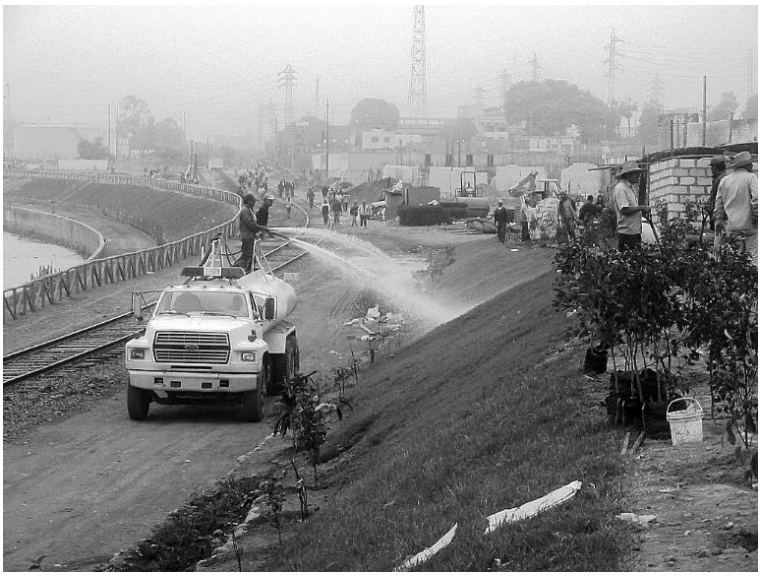

Figure 2 Irrigation of green areas by lorries using drinking water.

Image source for Figures 1 and 2: Ministerio de Vivienda, Construcción y Saneamiento, Peru

These issues are addressed by the application-oriented research project, funded by the German Ministry of Education and Research (BMBF), "Water supply and wastewater in megacities of tomorrow - Concepts for Metropolitan Lima (Perú) and elsewhere" ("Lima Water – LiWa"). This project aims at identifying and addressing the most important of these pressing issues by an analysis of the situation, development of ideas and plans of innovative, adapted wastewater treatment and management concepts which are adequate for the particular boundary conditions in the context of Lima. Particular emphasis is being laid on their sustainability under ecological, economical and social aspects. In this project, partners[1] from various disciplines from academia, the local water operator, industry and NGO sector from Peru and Germany are working together on a sustainable concept for management of this megacity, taking into account its specific climate conditions. Currently, the initial phase of this project within BMBF's "Research for Sustainable development of megacities of tomorrow" research programme[2] is ongoing, where an analysis of the situation in Lima is conducted and first solution approaches are being developed. As all projects within this BMBF programme, funding of this project is in two stages: after a preliminary phase of two years (2005 – 2007), successful projects (subject to continuation of the research programme by BMBF) will enter the main phase of nine years (2007 – 2016). More detailed development and refinement of concepts as well as implementation of solutions will form the second phase of the "LiWa" project. Funding applications for this main phase are underway. The project has several closely interwoven work packages, one of which is constituted by the activities on education and training, which will be described in the subsequent sections of this paper.

2. OBJECTIVES OF THE "LIWA" PROJECT

The overall aim of this project poses great challenges in research and application: It consists in the development, planning and implementation of concepts to improve the water supply and sanitation situation in large conurbations, taking into account technological, environmental and socio-economic

[1] The "LiWa" project team currently comprises of ifak Magdeburg (D), Pontificia Universidad Católica del Perú (PE), SEDAPAL (PE), Foro Ciudades para la Vida (PE), Dialogik (D), Technische Universität München (D), IEEM at University of Witten/Herdecke (D), Siemens AG (D), Hans Huber AG (D), and the Institute of Advanced Studies on Sustainability (D). The project team is being extended to include additional partners, including the National University of Engineering of Peru. www.lima-water.de

[2] See www.emerging-megacities.org for full details of BMBF's megacity programme and related projects

considerations whilst ensuring appropriate public participation and the consideration of all stakeholders' interests. The Metropolitan area of Lima has been chosen for a case study since it is characterised by a number of features typical of emerging megacities. Good cooperation with the Peruvian partners (water company, NGOs and academic sector) and the relevant Peruvian governmental institutions has been established.

In an initial step, currently undergoing and past projects are being scrutinised, and conclusions on yet open issues are drawn. Since one of the main goals of the project aims at closing the water and resource cycles within Lima, the development and application of modelling tools at different level of detail, considering overall urban water fluxes and various treatment schemes, including their economic aspects, forms one of the core elements of this project. Modelling allows for a better understanding of the complex interrelationships within the system, the analysis of its sensitive parts, the development of appropriate strategies for improving the system and a prediction of its future development. It is obvious that, due to the complexity and the heterogeneity of the system "Lima Metropolitana", adapted and individual solutions are required. Although the development of the concepts is not solely based on the modelling part, the application of models forms a strong instrument for evaluation of the concepts and their impacts on the system. In this context, research is also being carried out on the adaptability of treatment technologies to the Peruvian conditions and on development of "ownership" of sanitation concepts. Furthermore, full-scale adaptation and testing of various wastewater treatment technologies is envisaged for the project's main phase.

The project consists of a number of work areas, comprising *inter alia* of wastewater technologies, economic aspects and funding options, social aspects and participation, modelling for decision and participation support, education and training and will develop and demonstrate its approaches on a number of case studies. Education, training and capacity building activities are crucial for the success not only of this project, but also for the period after the project and the long term application, as well as for ongoing operational and financial improvement and success of the concepts to be developed. Therefore, these will be described in more detail subsequently.

LiWa puts particular emphasis on wastewater management since the solutions obtained here (such as the reuse of treated wastewaters) are expected to contribute to an improved water supply in the megacity's environment. Hence, the project addresses the following main issues:

- Research of the potential of innovative wastewater treatment technologies
- Evaluation of the concepts under technological, ecological and socio-economic aspects
- Modelling and simulation of urban water systems
- Decision support for adapted water technologies
- Elaboration of realistic refinancing strategies, considering revenues from international donations, public budgets, water tariffs and the willingness and affordability to pay
- Ensuring of communication and public participation in the decision making process
- Development of a prototype system
- Evaluation of concepts for data communication for water and wastewater systems
- Development of a guideline document and recommendations for the implementation of innovative systems, applicable for other cities too.
- Implementation of results
- Feeding of project results into research and education in Perú and in Germany

2.1 Technological Aspects

Traditional wastewater systems have been employed for quite a long time. Their main principle is the use of water as a means of transport not only for liquid wastes but also for solid matters. Along with the discussion on more sustainable water management concepts and principles these traditional concepts are now being questioned. Along with this discussion often advantages and disadvantages of

centralised and decentralised concepts have been debated (Harremoes, 1997; Otterpohl et al., 1997; Butler and Parkinson, 1997; Ho, 2005; Orth, 2007; and many others). Whilst the discussion whether decentralised or centralised concepts are the more appropriate ones is ongoing, the development of new sustainable technological solutions is most often based on the concept of separation of the different wastewater flows since this concept allows for the reuse and recovery of water and nutrients. Furthermore the general focus of today's discussion is on the sustainable production of energy by anaerobic treatment of particular compounds.

The project investigates the potential of different wastewater treatment systems and overall concepts based on the mentioned ideas. Due to the highly heterogeneous character of a megacity like Lima, the concepts will have to be adapted and integrated to each specific region, taking into account the locally prevailing actual and future boundary conditions. Due to the integrated and adapted character of the new concepts to be developed, the social and educational aspect of the LiWa project plays an important role in the development, evaluation and implementation of the new solutions. Although the project does is not preoccupied to specific technologies, the technologies to be evaluated will include concepts such as anaerobic, fixed-bed, membrane, SBR, MAP and microbiological treatment. Such systems are expected to have various advantages, in particular for fast growing megacities like Lima. The systems can be used in existing buildings and districts as well as in new ones. Different concepts and system sizes of potential for various parts of Lima Metropolitana will be tested within this research project. It is aimed at the reuse of the treated wastewater in agriculture, for irrigation of parks or for industrial purpose. The goal of this project is to develop and to test various types of this basic concept (differing, for example, by various layouts of anaerobic reactors, aerobic composting, SBR, membranes, fixed-bed reactors) and to assess its feasibility, not only under technical-environmental, but also under economic and social sustainability considerations.

The main technical aspect of the project is to develop new flexible, integrated and adapted concepts of advanced decentralised, semi decentralised and/or centralised wastewater treatment concepts that could also be adapted to different climates and wastewater compositions in different countries.

2.2 Assessment of Concepts

Having set up and tested various scenarios of wastewater management, it is important to develop and verify (applied to the case study) a lean methodology for the assessment and evaluation of alternative concepts and technologies for water and sanitation linked to all relevant restrictions and criteria of wastewater in a megacity environment.

This task will be supported by the development and application of modelling tools, considering water fluxes and various treatment schemes, including their economic aspects – both on a "microscale" (e.g. individual plants in detail) and on a "macroscale" (main water and resource fluxes within Lima Metropolitana). Section 4 comments on such a "water in a megacity" modelling tool .

2.3 Economic Evaluation of Alternative Options under the View of Sustainability

Any economic evaluation which covers sustainability aspects must consider all (*i.e.* not only monetary) costs, which are related to ecological and social aspects. A mere calculation of expenses for water facilities etc. would not be sufficient. Subsequent costs (Life Cycle Assessment), external costs (and benefits) etc. will have to be taken into account. These issues will be considered in an appropriate work package, taking into account the specific conditions and data of and for Lima, including *inter alia* the value of recycled water, the costs and benefits of labour, the foreign currency exchange rate, and the price of energy.

In order to overcome the difficulties with sustainable operations and maintenance of water and wastewater facilities, which are clearly the bottleneck of success in many regions world-wide, new concepts of financing and refinancing, such as, for example, a franchise model, are being analysed.

2.4 Partner Communication and Involvement

Among the objectives of this project is to develop a partner communication strategy, an information exchange platform and a participatory decision-making structure which will secure direct interactions among all parties involved and a clear participatory structure for designing scenarios and technical-organisational solutions to the problems of water management. Outcomes will be an instruction manual produced in co-operation with main actors about implementation and required changes for all affected groups and an ongoing public relations concept for the implementation phase.

2.5 Ensuring Social Acceptance

The scope and ambitions of fresh water supply and sanitary management have increased, meaning that sanitary management is engaged in technical, social and moral issues and affects more people than it did in the past. These developments point to an increased need for public participation. In order to achieve this in an effective and efficient manner, the following tasks are envisioned:

- Involving local authorities, stakeholders and representatives of the affected public in awareness-raising measures and in a public participation process that can be monitored and evaluated,
- Disseminating and documenting knowledge on lessons learnt and about how to use and evaluate participatory methods.
- Empowering and enabling local partners to evaluate the effectiveness, relevance and usefulness of different participatory methods.

3. EDUCATION AND CAPACITY BUILDING

The main objective of the education programme is to train students, technicians, other professionals, employees and authorities in integral and participative management of water resources.

In Peru and especially in cities such as Lima, the local population is often lacking awareness of the fact that they live in a city located in the middle of an arid zone where the scarce resource is the water. It is necessary to change the citizens' habits in order to promote an efficient use of water in all cities. It is important to transmit the protection of the water resource through campaigns, TV programmes, radio, newspapers and also make changes in curriculum of school and universities. The Peruvian government has launched its 'Programa Agua para Todos' ('Water for all' programme) in the end of 2006 in order to tackle problems like insufficient coverage of water services, deficient sustainability of the existing systems, current tariff structure, which does not cover the investments, operating and maintenance costs and institutional and financial weaknesses.

With regard to university education, it has to be noted that, for many students, it is very difficult to do their thesis once they finish their studies at the university. This difficulty is due to the fact that most of students cannot afford to embark on a research programme (because they belong to families with medium to low income) and they do not have the enough knowledge to start a project, possibly since they do not have the access to information of all available technologies which could be applied. Afterwards, there is a lack of specialised professionals, which not only know the main concept of existing technologies but also have experience designing and operating them. The LiWa project will facilitate the application of more technologies in Lima, which will enable students to improve their training by including – besides other educational measures - technical visits to the new projects as part of the students' curriculum.

3.1 Description of Education Programme

Important parts of the educational / professional development activities will be developed in close coordination with SEDAPAL, the enterprise in charge of the drinking water and sewerage of Lima and

partner of the LiWa Project. In addition, other areas such as small towns in periurban locations, highlands or the forest part from Peru should also be taken into account since people living in those areas usually get diseases originated by the scarcity of water or by water pollution.

In order to achieve maximum output and efficiency from this project, it also is planned to transfer the obtained results from this project to teaching and project supervision activities. Corresponding curricula will be developed, also serving as a base for teaching activities elsewhere and, thus, also supporting and enhancing the international scope of university and professional development teaching. In accordance with the "Agua Para Todos" programme of the Peruvian government, the aim of the project will also be to develop technical unified standards for dimensioning and operation of the different kind of treatment plants.

Proposed trainings involve technical and professional level and students from universities. The basic topics involved are wastewater treatment and its reuse, conventional and alternative concepts of sanitation, integral and sustainable management of water. Activities from the group will be done with the contribution of other members from the LiWa Project.

All trainings are going to be prepared by a selected group of German and Peruvian specialists. During the Period 2007 to 2016 the following trainings are expected to be done:

1. Six trainings given in the universities in the LiWa Project, which will incorporate LiWa´s results in its curricula: design of wastewater treatment plants, environmental management, environmental solid wastes management, environmental impact assessment, treatment of industrial solid wastes, technical for using of treated wastewater and public health.
2. Two annual trainings for SEDAPAL´s professionals: related to applied environmental management of wastewater treatment plants (WWTP) and technologies involving concepts of anaerobic, fixed-bed, membrane, SBR, sludge treatment and pathogen removal.
3. Two annual trainings for main employees and authorities from the Peruvian sector related to applied environmental management of WWTP and wastewater treatment technologies.
4. One certified annual training for technical operators of WWTP in Peru: It is suggested to implement a variety group of trainings oriented to specific technologies feasible for different towns.
5. One well trained net of WWTP's operators of SEDAPAL and municipalities after 2008. It is suggested to have periodic meetings of the related net in order to update methods and promote the improvement of their activities.

3.2 Milestones and expected results

The "Education and Capacity Building" workpackage of the LiWa project is is expected to yield the following results:

1. Undergraduate and postgraduate curricula related to Environmental Engineering courses of the partner universities are going to be fed in with LiWa's results and research applied projects.
2. Installation of trainings through partner universities, which are going to be offered by LiWa for professionals, main employees and authorities.
3. Official and certified training for technical operators of wastewater treatment plants (WWTPs).
4. Interchange at technical level between WWTP operators of SEDAPAL and other water operators.

There is a strong need of trainings, which will be covered. Those trainings will help sustainability in existing WWTP, which most of the time collapsed because there was no or not sufficient maintenance of the WWTP in many municipalities located in Peru. In addition, the education programme will help main employees and authorities to select the best WWTP´s Projects in the best location.

4. MODELLING

A core element of the project is also constituted by modelling. Modelling, i.e. the (approximate) representation of the urban water system of Lima Metropolitana and its processes and interactions, is carried out on two levels: On a *micro-modelling* scale, individual parts of the system (e.g wastewater treatment plants with conventional and innovative technologies) are modelled in detail, so as to assist in plant design, layout and operation, thus supporting model-based infrastructure planning and important investment decisions.

A second line of model development work is focussing on *macro-modelling* aspects, i.e. modelling of the water and resource fluxes of the entire urban water system of Lima Metropolitana, obviously in a simplified way and allowing for transferability to other megacities. Development of such a simulator, including design formulas and means of incorporation of capital and operational expenditure, and fed with the data of the 44 quarters of Lima, is currently ongoing (cf. Figure 3).

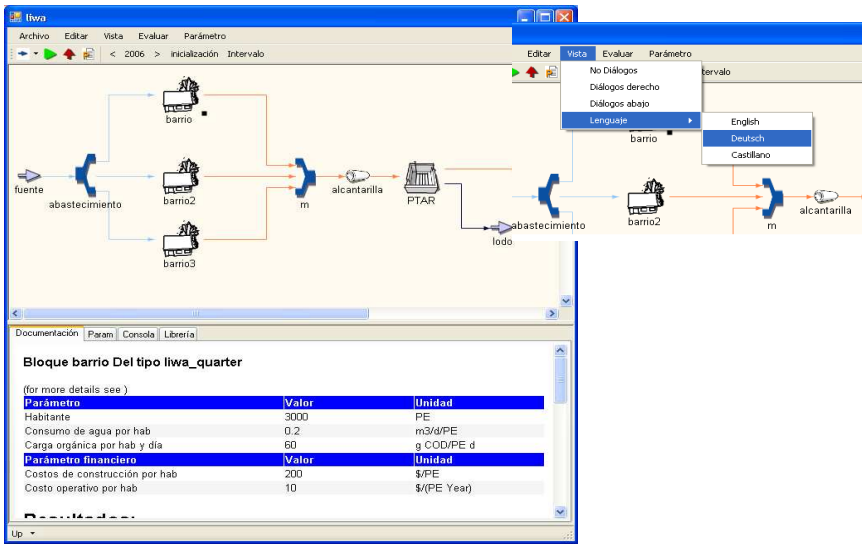

Figure 3 Initial prototype concept of macro-modelling of urban waters in Lima Metropolitana

Macro-modelling of water in a megacity will hence serve for a number of purposes and thus forms an integral part of various work lines within the LiWa project:

- Support of technological and economical evaluations, considering the impacts on the entire system
- Visualisation of effects of scenarios and operational variants; this will also support raising awareness and creating ownership for innovative solutions since the model can be used also in stakeholder meetings and citizens' fora. Therefore modelling supports discussions between stakeholders and thus strengthens participatory approaches in water management and facilitates informed decisions, as also has been postulated by WBGU (2007).
- Support of education and training: Models, providing students (as well as professionals) with the option to experiment themselves with potential solutions, also under varying boundary conditions (e.g. climate change!) can contribute to the learning process and educational success and complements (static) textbook material by a dynamic component.

5. CONCLUSIONS

Technological wastewater concepts alone cannot solve the problems of megacities since the problem is not solely of technological nature. Technologically advanced solutions can be useful but do

not constitute the sole prerequisites for more sustainable cities. Any technological concept for such heterogeneous and complex urban systems such as it is the case in Lima or other megacities can only make progress if engineers and all the other sectors of our society are willing to work together. This involves the economical side as well as the social dimension. All factors being influenced by and influencing the urban water and wastewater cycle must be accounted for. Children must be made aware of the importance of the resource water since they can naturally have a strong influence on the situation in the future and in the presence (by exerting pressure on their parents). Women need to be aware of the situation since they are usually the people using big parts of the water in the household.

Community members must be trained to be able to maintain, adapt or even improve the technologies and management concepts on a household or community level. This work should be supported and promoted by authorities in the project phase and beyond.

Students, engineers and economists must be trained at the universities and be made open minded for new unconventional approaches and maybe even new job profiles and even new job trainings must be created. Modelling plays an important role also within this context. As reported by Wilderer (2005), experience suggests that motivation of the users to use new technological systems properly is relatively easy, especially when modern participatory approaches are used and intensive education is provided. The strong importance of the social level is in full agreement with the rest of the engineering community. Similar statements have been made by many authors emphasising the importance of a holistic approach in order to reach a more sustainable urban water management concept (Harremoes, 1997; Jeffrey et al., 1997; Schertenleib, 2005; Butler and Parkinson, 1997; Wilderer, 2004; Rouse et al., 2005; Asano, 2005; and many more).

5. ACKNOWLEDGEMENTS

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