Varis O. & P. Vakkilainen Water for Cities - From Sectorial to Holistic Thinking.

Habitat II. Preparatory Round Table, Institute for Housing and Urban Development Studies. 4–6 October 1995. 11 s.

HABITAT II Preparatory Round Table: HUMAN RESOURCE DEVELOPMENT FOR BETTER CITIES, Institute for Housing and Urban Development Studies, 4-6 October, 1995, Rotterdam, the Netherlands.

Water for Cities
— From Sectorial to Holistic Thinking

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1 INTRODUCTION

The academic world has undergone and is perhaps increasingly experiencing a tendency of specialization. The education is splitting into more and more specific, narrow, and profound disciplines. This process is usually, though very unfortunately, followed by the erosion of generalistic views over the society and the nature. Academic incentives, resource constraints and many other factors contribute to this development. Societies come along; sectorial approaches to development have dominated, too much in many ways, we argue. It is not difficult to find examples, where too narrowly comprehended development schemes have created more problems than they have solved. For instance, in the water sector, such cases include boring of deeper wells that has led to overexploitation of groundwater resources and enhanced desertification; creation of water markets with "proper" pricing aimed at better cost recovery and capacity building but causing creativity in boring private low-quality wells and making holes to water pipes to extract water at no cost; improved water supply without proper wastewater treatment or even sanitation that has caused environmental deterioration and health problems; building of dams without proper analysis and remediation of adverse environmental and social effects, just a few examples to give a flavor. Evidently, highly educated people should possess a generalistic view to avoid such undesired development paths, because much of the development is in their hands anyway.

This paper discusses the present challenges to human resource development to support sustainable infrastructure development in urban centers, particularly in the Third World, with special reference to higher education in the water sector. First we survey the major problems and challenges to water resources that are created by the urbanization development as it proceeds on the globe today. Profound changes in paradigms of water management, education, infrastructure, etc., are needed to meet these challenges with success. The issue is discussed, with emphasis on the importance of holistic views to the social, political, natural, economic, and technical complexity and interactions. Education — at University level in particular — should take these views into account much more than is done at present.

2 PROBLEMS AND CHALLENGES

Urbanization: expanding pressure for the environment and water resources

The world population grew with 91 millions in 1992 (Brown et al. 1993). The growth in urban areas — due to both migration and natural growth — accounts for roughly four fifths of this figure. As the growth rate of the global human population is around 1.9, and in Africa it is around 2.9, the rate of Third World cities with over one million inhabitants was approximately 5.6 in years 1980-1990 (Drakakis-Smith 1987). This growth rate implies 72% increase in a decade. Some cities, in Africa in particular (e.g., Addis Ababa, Kinshasa, Lagos) exceed doubling of their population in one decade. Urbanization in the Third World is remarkably faster and the cities grow bigger than has been experienced in industrialized countries. Most of these changes take place in a manner that is controllable only to minor degree by authorities. Moreover, the mega-cities often grow with the highest rates.

This development puts a heavy pressure on water resources and environment, and raises problems that need more interdisciplinary solving patterns than we are used to at present. The growth in many cities is so rapid that the infrastructure has enormous difficulties to follow the needs, and often cannot develop with the same rate. In many cases, the infrastructure dates back to colonial times and the deterioration problems are usually added to the capacity issue. The same type of problems but in much smaller extent are also frequent in industrialized countries, in former communist countries in particular. Much of the population, particularly those living in squatter settlements have no access to safe drinking water and proper sanitation. Waste management including waste water treatment is underdeveloped. Evidently, any development in infrastructure is bound to fail unless it is in concert with the type and level of the rest of the infrastructure, with institutional development, with economic and financial constraints, with political climate, and with human resources at place.

Water scarcity grows rapidly

Water quality and quantity problems must be seen as two sides of the same coin. Too often this is forgotten. In terms of water infrastructure, the urban issues are increasingly linked by rural water uses, due to the allocation problems of this growingly scarce and increasingly polluted resource. When allocating more and more water to urban centers, the other water uses — not the least food production which already contributes to over three quarters of all water use on the globe — are increasingly subjected to water shortage. Cities simply need food, which must be produced with rapidly growing efficiency to meet the escalating demand. Major local and regional problems are also due to groundwater mining and pollution due to unsustainable water use in urban areas. Figure 1 shows that the share and the number of the world population that will be suffering from the shortage of water is in an expanding phase. The potential climatic changes are likely to add to these problems. These results do not include water quality problems, which make the water scarcity issue still an essentially more severe one.

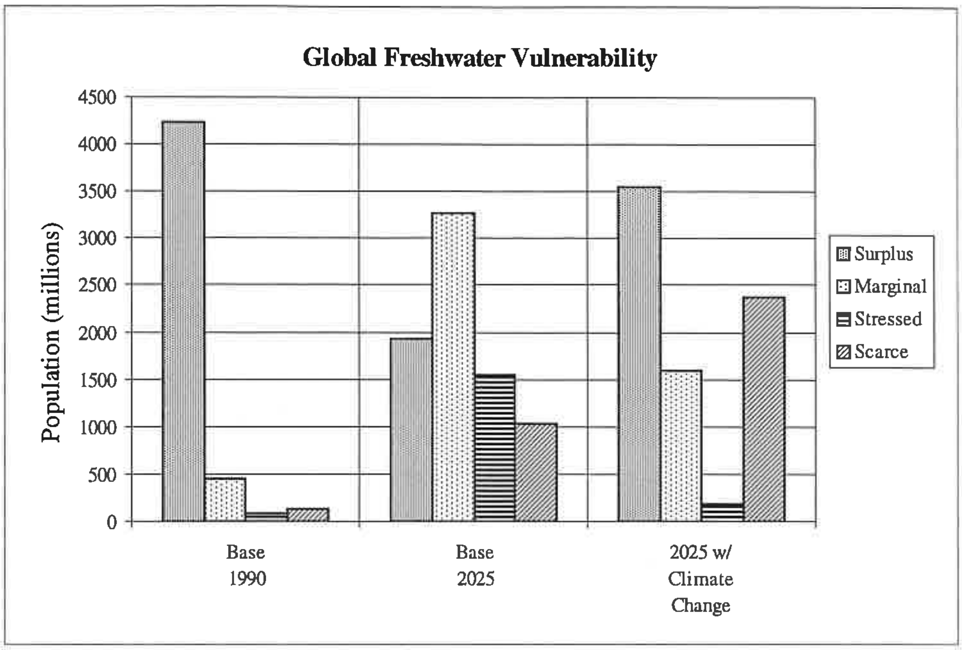

Figure 1. Vulnerability of the global population to water supply deficits using a use/availability approach (Strzepek et al. 1995). Surplus: use/availability low and supply/capita high. Scarce: use/availability high and supply/capita low. Marginal and stressed fall within this combined criteria matrix.

The sustainability concern

Agenda 21 of the Earth Summit '92 in Rio de Janeiro postulates the concern and urgent need to plan and implement environmentally sustainable development strategies. Evidently, in addition to the environment, the sustainability criteria should incorporate also the exploitation of natural resources, development of human resources (health and education) and offering an efficient macroeconomy.

When exploring the current development pathways of human demographic development, and particularly that of urbanization and mega-cities, one easily ends up with a conclusion that any level of sustainability in their future development is a distant dream with no possibilities to be managed in foreseeable future but in minor details. However, this is where we simply must start from, but keeping in mind the entire problem setting with the population pressure, resource scarcity, environmental problems and socio-economic realities.

Without making an attempt to contribute to the rapidly growing literature on the definitions of sustainability, one basic point deserves mentioning here, which is not sufficiently emphasized in mainstream discussion on urban water infrastructure. Evidently, water management should attempt to close material and energy cycles as much as possible (e.g., Niemczynowicz 1993). This requirement is in fundamental contradiction with the present type of urbanization process, in developing countries in particular. Instead, the high population densities should be avoided, unless the waste produced in cities can be recycled to the production of food or other mass products. The wastes, if discharged to water courses and aquifers, contribute essentially to the water scarcity through pollution (Figure 2). Overexploitation (mining) of aquifers is a rapidly growing, which clearly is an unsustainable tendency.

Figure 2. Closing material cycles is one of the basic prerequisites for sustainable resource use. With rapidly growing, uncontrolled urbanization process, sustainable use of water and land resources becomes increasingly difficult with tools and resources available in practice.

Vicious circles under control

Urbanization and water scarcity are among the major problems the mankind is facing now and still increasingly in the coming decades. They both, including the attempts to fight them, are likely to have vast ecological effects even in global scale, be probably sources of social and political instability in many locations and regions, and yield human disaster to an innumerable amount of people.

The uncontrolled urbanization should be combated in many ways, also through infrastructure decisions. Decreasing the urban pull and rural push forces should still be a high priority topic in development programs (Figure 3). Urban rural interactions should be realized, they partly have the same infrastructure (energy, transportation, telecommunication, water, etc.). Their close connections are particularly evident in the water and agricultural sectors. Urban primacy is a reality in many countries, but rural primacy might neither work very easily, as the experience from, e.g., Pakistan shows. Rural push is particularly important in developing countries with a shift of agricultural production to cash crops using intensive irrigation with decreasing labor force. If a city infrastructure is very developed in comparison to the rural one, it will in turn enhance urbanization through urban pull.

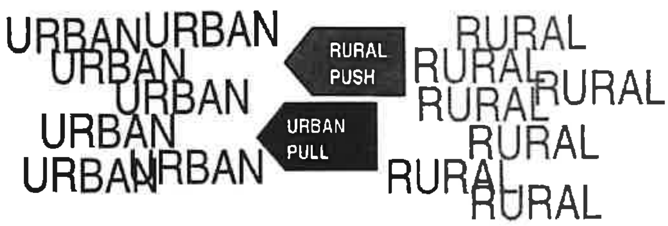

Figure 3. Water management and infrastructure decisions are among the many components of rural push and urban pull forces.

When discussing the urban energy sector development, Mustanoja (1995) makes an important point; try to cut the vicious circles in urban development, and to make the urbanization and infrastructure development more controlled processes (Figure 4).

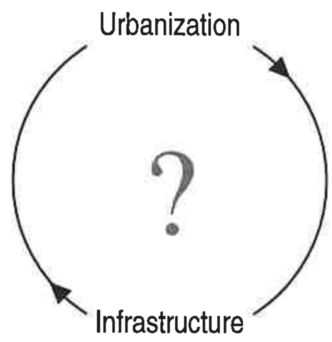

Figure 4. City growth appears to outpace infrastructure development in many Third World cities (cf. Somlyódy et al. 1995).

This, however, requires huge amounts of political and economic power and will, especially over the informal sector. These are often lacking. Recent developments in former centrally planned economies including increasingly even China are vivid examples of collapsing formal sectors that tried to keep a strong control over the opening societies. How the success stories of today — e.g., Singapore, Western Europe — will develop in decades ahead, remains to be seen.

Appropriate and affordable technology

A much argued issue is the type of technology that should be implemented in the urban water infrastructure —water treatment in particular — in the Third World. Figure 5 shows selected cities in the industrialized countries and in the Third World, with respect to the level of wastewater treatment, population growth rate and GNP per capita. Niemczynowicz (1993) argues, that the water treatment problems should find alternative solutions in the Third World. The level of investments on environmental protection range globally between 0.5% and 5% of the total GNP, being typically higher in countries with higher GNP. In a poor country with GNP per capita around US$ 200 to 400, the spending to environmental protection is bound to be well below US$ 5 a year. Alternative, less capital intensive solutions, which simultaneously fit together with available human resources and infrastructure are desperately needed. Many ecological and biological low-input solutions, plus labor-intensive approaches instead of capital and equipment intensive ones often enter the discussion.

3 NEED FOR A HOLISTIC VIEW

The sectorial, fragmented and narrow approaches to science and engineering that are prevalent in the education system and consecutively to the whole societies in present-day industrialized countries, are one of the major causes to the unbalanced development in many ways, not at least in the urban-rural disequilibrium and disparity, and extensive urbanization in the Third World. In the water sector, the voices calling for integrated approaches and holistic views become ever louder and the argumentation gets increasingly rigorous (cf. Falkenmark & Lindh 1976, Biswas 1976, Kinnersley 1988, El-Ashry 1993, Somlyódy et al. 1995), but still strictly sectorial, even jealous approaches tend to predominate. The same applies to infrastructure issues.

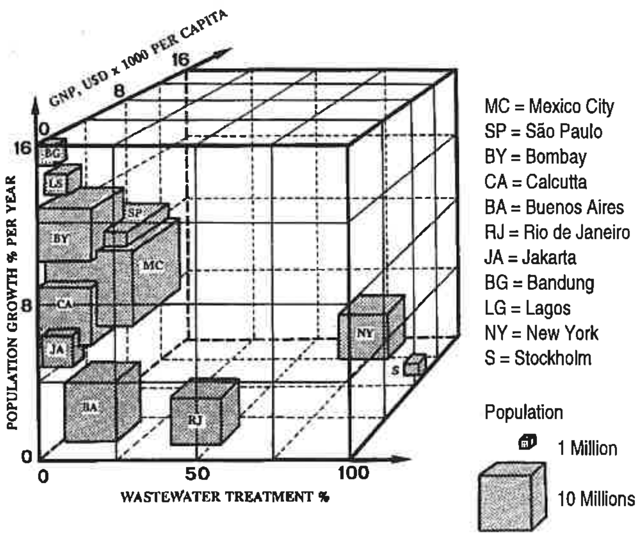

Figure 5. Relation between wastewater treatment capacity, GNP and rate of population growth in selected large cities (after Niemczynowicz 1993).

Changes needed in water management paradigms

Fresh water management including urban water infrastructure witnesses a number of trends or at least it should witness them in the close future in order to work towards sustainability. Somlyódy et al. (1995) have accomplished the most significant of them in Table 1. Evidently, the education is subjected to vast challenges in order to be able to provide professionals who are able to cope with the issues raised in the Table. Yet, it is mandatory to take these issues in much higher in the agenda of water related human resources development programs.

Urban infrastructure

There are many ways to work towards a sustainable urban infrastructure. However, none of the sectors or subsectors — e.g., water supply and sanitation — can manage it alone. All the pieces of puzzle should fit together, the system components should be more or less in balance, including different sectors of urban service, political, economic and financial realities, social issues, human resources, institutionalization and operations management such as pricing, and not to forget the constraints due to most simple things, water and food availability and the prior importance of primary education. This is unavoidable, in order to meet the very real challenges directed to them by the global urbanization development. A particular challenge is to make any attempt — through balanced and integrated water management — to try to avoid uncontrolled growth of mega-cities by tackling both the urban pull forces and rural push forces that are behind the process. Another major point is the alarming trend of growing water scarcity and vulnerability, that should be realized much more than done at present (see Strzepek et al. 1995). Variation of cases is high and solutions that are applicable in a certain city may be most inappropriate in some other city.

Table 1. Trends in fresh water management (Somlyódy et al. 1995).

PAST	PRESENT	FUTURE (Expected and/or Desired)
(1) General		
Local problems		Increasing scale
Fast response, reversibility		Delayed responses and irreversibility
Limited number of pollutants		Multiple, sophisticated interacting pollutants
Point sources		Diffuse sources
Single media (water)		Multi media (water, soil, air)
Static, deterministic, foreseeable		Dynamic, stochastic, uncertain
Regional independence		Importance of global interdependency
(2) Control Type		
"End of the pipe"		Source control, closing material cycles, land use management, concern on large scale projects*
Technical		Non-technical elements*
Discharge standard - rigid		Use attainability - flexible
(3) Infrastructure and Treatment Systems		
"Traditional technology"		Special treatment methods (biol-chem treatment, high-tech processes, upgrading, appropriate technology, natural treatment, small-scale treatment). Emerging new traditions and technologies
Landfilling of solid wastes		Increased reuse and recycling*
Large scale control and exploitation		Regional and small scale development, management and conservation. Flood plains, wetlands, and other ecosystems as valuable resources.
Massive, capital intensive urban infrastructure		Localized, small scale, creative infrastructure development*
(4) Monitoring		
Local measurements		Networks, remote sensing, continuous measurements
Conventional parameters		Special parameters (micropollutants, eco-toxicology, biomonitoring, etc.)
Monitoring of water		Integration of effluent and ambient monitoring and aquatic ecosystem monitoring
Poor data availability		Improved availability (data bases, digital maps, telecommunication), integrated information systems
Hands off "my" data policies		Open information flow
(5) Modeling		
Individual issues (processes, control, operations, planning, etc.)		Integration (model library, DSS, GIS, expert systems, etc.)
Limited, numerically based results		Scenario based and visual. Use of multi-media to explain complex ideas
Use by experts		Use in administration, meetings, etc.
One correct paradigm - single discipline		Many paradigms known and accepted within and between disciplines
(6) Planning and Project Evaluation		
Poor/narrow definition of objectives		Clear goals and objectives*
Short-term view		Long-term view*
Cost evaluation		EIA, risk and multiobjective evaluation, social and political impacts*
Little concern on failures and adjustment needs		The future is never certain: reliability, resiliency, robustness, and vulnerability*
Positive and negative impacts separately		Positive and negative impacts together
(7) Science and Engineering		
Science does not drive actions		"Science for Action" and combination of broad, emerging scientific concepts with engineering*
Problem isolation and engineering solutions		Improved planning*
Interdisciplinary gaps and barriers		Integration of quantity, quality, hydrology, economics, politics, social science and management*

TABLE 1 Trends in fresh water management (Continued).

PAST	PRESENT	FUTURE (Expected and/or Desired)
(8) Legislation, Decision Making Institutions and Development		
General rules and rigidity		Specific rules and flexibility*
Fast implementation (a misbelief)		Process view*
Little enforcement		Improved Enforcement
Command and control		Polluter/user pays, improved policy instruments
Confusing institutional settings		Clearer structures and responsibilities, less barriers and mismanagement*
Decisions by politicians and administration		Public awareness and participation, NGOs, and enhanced communication (scientists, planners, community, government, etc.)*
National policies		International policies*

* Desired trends represent an attractive development course for water resources.

Water supply and sanitation

In urban water infrastructure development, water and sanitation should be seen as one entity and they should be developed together (Figure 6). This is not often the case. Most of the public health effects of water supply, if performed without proper sanitation, will be drained off. Moreover, water and sanitation projects should be accompanied with education, public awareness and community involvement. These issues are also crucial when increasing the efficiency of water supply systems.

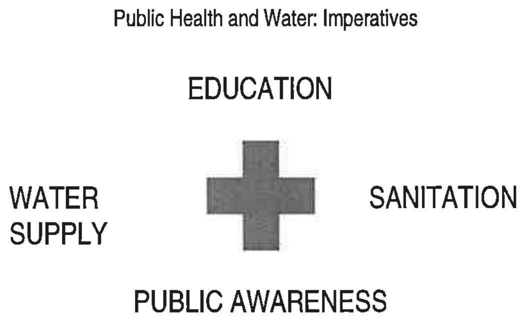

Figure 6. Water supply and sanitation are inefficient in terms of enablers of public health if done without one another and without proper education allowing public awareness.

Top-down and bottom-up

Another challenging scheme is to further develop solutions that allow the integration of the top-down (governmental) and bottom-up (localized markets along with public awareness) implementation and control of urban water infrastructure. The world is too complex to allow the acceptance of only one direction. Apparently, with increasing temporal and spatial dimension of the planning process, more integration to other sectors is needed (Figure 7). At the contingency planning level, all sectors are thoroughly interwoven. These overlaps gradually fade in importance when going through strategic planning (policies, plans, programs), tactical level (annual water allocation etc.) to operational level (plant or reservoir operation, or short term remedy, etc.). The growing recognition that the different aspects of water management form a continuum (e.g. Serageldin 1995) appears to reveal that the concern of water is no longer only on operational or tactical issues as has been typical to the past.

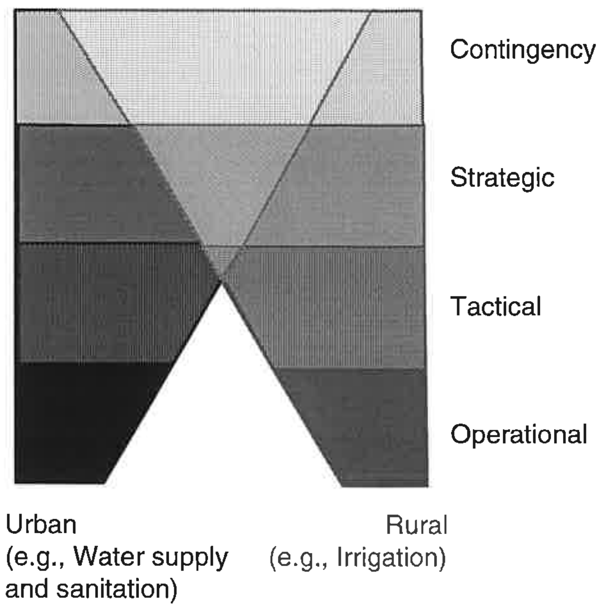

Figure 7. With increasing scales, the issues become more integrated.

Higher education

Many of the problems, challenges, and alternatives to higher education in order to better handle the water issue in cities have been discussed. The two focal issues are (1) each individual with higher education should possess a generalistic view to the society, science and technology, and feel responsibility which should go hand in hand with the power and privilege due to education (Figure 8), (2) the educational system should encourage and teach the individuals to include the question *why* in their personal agenda, besides the question *how*, which is too dominant, and even dangerous without the concern of the question *why* (Figure 9).

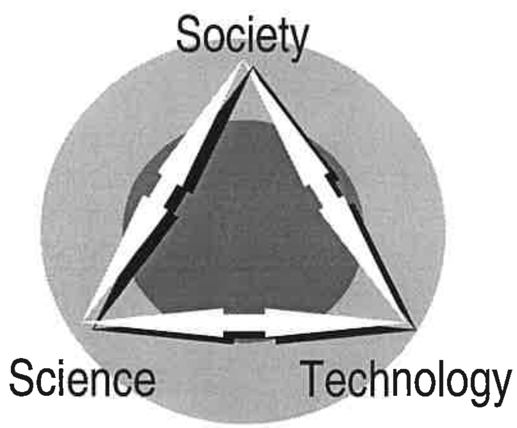

Figure 8. Higher education should be able to provide, in addition to discipline-specific expertise, a generalistic view over the human society, over technological possibilities and options, and over the scientific facts and approaches.

Evidently, higher education is just one part of human resources development. As was emphasized in the case of urban infrastructure, also the higher education should fit the rest of the society, yet being hopefully somewhat ahead of the overall development. All levels of education needed, and the primary education is clearly the prerequisite for balanced development. Public awareness and participation which is increasingly emphasized today, requires education at very principal level. Yet, organization of primary education is impossible without Universities.

Water related education at higher levels has traditionally been split into several disciplines including several engineering subjects (hydraulic engineering, water resources engineering, water supply and sanitation, etc.), a number of subjects in applied sciences (limnology, hydrogeology, etc.), and in pure science (hydrobiology (botany, zoology, etc.), hydrophysics, aquatic chemistry, etc.). Though it is mandatory to go further and further into details in these important fields, the overly reductionistic approach should be balanced by providing more of general topics to individuals. In engineering education, for instance, this means more education in science (natural, social and political) and in pragmatic issues such as institutions and law. This would change the approach from one profound technological focus (vertical) to include another, horizontal dimension, not as a by-product as is typical today, but as a field of strong expertise, not a most profound one, but rather a holistic view.

In hydraulic engineering, for instance, the comprehension over water has traditionally been restricted to the convey of water through a technical or semi-natural system in a desired way (minimize energy loss, seepage, erosion, etc.). This is no longer enough. A view on environmental issues, water quality, resource management, project evaluation (financial, technical, economical, environmental, social, informational, and institutional, cf. Munasinghe 1993) is necessary. Not at the level of knowing all details, but to understand the issue (project, plan, policy, program) as an entity. At the contingency planning level, such as city development, this is still more crucial. The world has evidenced too many cases that have been fully successful at detailed levels, but disasters as a whole. One could continue to other disciplines, and the same outline would apply to them as well.

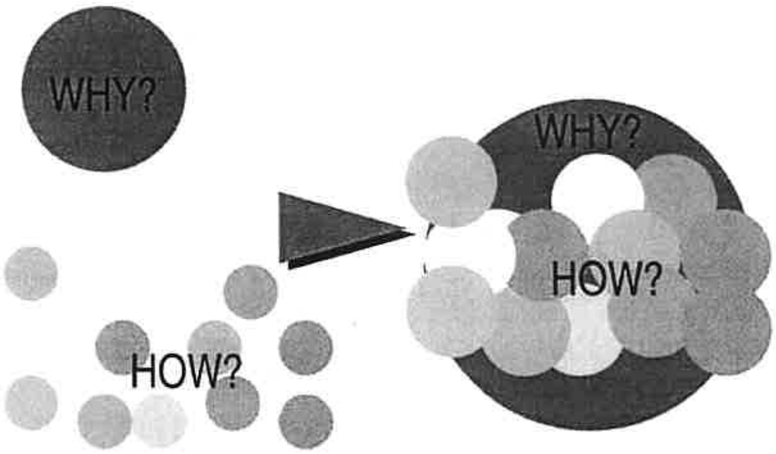

Figure 9. Higher education should be able to provide, in addition to discipline-specific expertise ("know-how"), also enough background to comprehend the driving forces and consequences of the development ("know-why").

We have a plenty of positive experience in taking such steps at University environment. As an example (not the only one), already since 1961, the water engineers have been offered education in quality of natural waters at Helsinki University of Technology. This is unusual to European Technical Universities. Many students continue a bit further, taking courses in ecology and environmental issues at the University of Helsinki, since the policy has been to provide freedom of choice to students, even to choose courses among the supply of some other Universities. This has proven to be a motivating approach, encouraging students' own awareness, allowing cross-sectorial studies, and most useful to the development of the water sector at the national level. The present call for the comprehension of environmental and social impacts has been well taken by the engineering community.

4 CONCLUSIONS

- ◊ The importance of improving education and public awareness should be high in any development agenda.
- ◊ Fragmented, strictly sectorial approach to development of human habitats may create more problems than it can solve.
- ◊ This can possibly be most successfully combated by providing holistic views in education, at University level in particular.
- ◊ The water in cities is not only water supply and sanitation. Instead, it must be seen as a part of a continuum of natural resources management and human societies.

Acknowledgment

This study has been partly funded and supervised by UNU/WIDER under the special Finnish Project Fund, which is supported by the Ministry of Foreign Affairs of Finland.

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