

INTEGRATION OF WATER AND SANITATION – A CHALLENGE TO REACH SUSTAINABILITY GOALS

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ABSTRACT

Possible benefits of integration of water and sanitation are discussed based on results from a Polish-Swedish research co-operation project supported by the Swedish Institute (SI). A relationship exists between total pollution emission and resources depletion, population, produced goods per capita, and pollution emission and resources depletion per unit of goods. As population and products per capita grow pollution emission and resources depletion per unit of goods must decrease significantly each year to comply with sustainability. Integration of water, wastewater, and solid waste handling and its relation to energy is discussed as a way to improve the direction towards sustainability and to use ecology concepts on water and sanitation in municipalities or river basins.

KEY WORDS

Integration, Poland, sanitation, sustainability, Sweden, water, waste

SUSTAINABILITY CONCEPT

The Brundlandt report made the well-known definition of sustainability as “...development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. Sustainability includes a resource and a pollution component meaning that society for sustainability must be able to continue its mode of operation on a long-term basis without exhausting its resources or causing environmental damages due to pollution emissions. Problems to reach this goal are related to population growth and production of different goods (clean water, food, energy, consumer products, etc). The famous MIT report to the Club of Rome (“Limits to Growth” issued in 1972) gave the key conclusion that “If the present growth trends in world population, industrialization, pollution, food production, and resources depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable result will be a rather sudden and uncontrolled decline in both population and industrial capacity”.

This strong warning can be discussed based on the following relationship between total pollution emission and resources depletion, population, produced goods per capita, and pollution emission and resources depletion per unit of produced goods, i.e.:

Pollution emission and depletion of resources = (Population) * (Produced goods per capita) *
(Pollution and depletion of resources per produced goods)

The relationship shows that sustainable development is a function of social, cultural, economical, technical, etc aspects as obviously for population (present population, population growth, urbanization, age distribution, etc) and produced goods per capita (consumer behavior, life style, employment, GNP per capita, income distribution, etc). The third term related to emission and depletion of resources per unit of produced goods has a strong basis in natural science and technology, but is also influenced by other areas as juridical aspects (discharge limits, forbids to use certain substances, etc), economical aspects (taxes, subsidies, etc), administration, organization and management. Sustainability is a multidisciplinary area with its influence from a local level (as Agenda 21) to international agreements (millenium goals etc).

APPLICATION ON INTEGRATED WATER, SANITATION AND ENERGY SUPPLY

The general relationship between total pollution emission and resources depletion, population, produced goods per capita, and pollution emission and resources depletion per unit of produced goods can be specified related to different applications as water and wastewater treatment, solid wastes handling and energy production.

Many specific problems are related to population. It has been estimated that more than one billion persons in the world live on less than one dollar per day. In an UN declaration the target is that this large fraction should be less than the half in year 2015 and it has been estimated that the target can be achieved if rich countries invest half of a percent of their revenues. On a global scale reaching goals of access to safe water, sanitation facilities and energy means a transfer of resources (money, knowledge, etc for investments, operation and maintenance of facilities) from the rich part in the world to the poor part. Many specific problems are also related to population growth, migration of people from rural to urban areas, special problems related to migration due to conflicts or as “environmental refugees” due to environmental destruction.

Produced goods per capita in water treatment can be expressed as water consumption per capita (for instance in households in a municipality) or as water consumption per unit of produced goods (for instance in an industry). A high water consumption in households (for instance above 150-200 l/person, day) often means low maintenance (as a high percentage of leakage from the water net), low quality of facilities inside houses (type of toilets, valves, etc) and bad management (including financing, supervision, and information to consumers). Water conservation in industries is necessary at present for cost-effectiveness of production due to costs for water, for wastewater discharges and economical gains in internal recycling of materials and energy.

Wastewater handling means production of a certain amount of treated wastewater per capita and sludge per capita. Emissions of pollutants to air, water or sludge should be minimized and resources recovery is necessary in an eco-cycling and sustainable society.

Solid waste management has the same goals to minimize emissions during handling and recover and recycle materials and energy. Energy production involves production of a certain amount of energy per capita in different forms as electricity and heat and with constraints to minimize pollutant discharges and recover rest products (as ash) during the energy production.

Water treatment, wastewater treatment, solid wastes handling and energy production, thus, include handling of a certain input as surface or ground water for water treatment, wastewater (in its different forms as urine, “black water” or toilet wastes, “grey water” or bath, dish, and washing

water, storm water, storm sewage, process water, and cooling water), wastes from municipalities and industries and oil, coal etc for energy production. All these activities must minimize pollution emissions and resources depletion to reach sustainability under the pressure of increasing population and demands of increasing resources per capita in the form of water, food, goods and energy. The increase is especially a concern in developing countries.

The need for development may be illustrated by a calculation example. If, for example, sustainability concepts requires a yearly decrease of pollutant emissions and resources depletion of 3%, population and per capita production are each growing 3% every year the emission load and resources use per unit of produced goods must be decreased by about 9%. With regard to the population growth, increased production of goods together with ambitions of sustainable development much more efficient technologies must be developed and put into practice.

Emissions should consider variations in scale (local including labor safety, regional, global etc) and time. Resources use can be seen very wide including not only natural resources as ground water, oil and minerals, but also space needed for facilities, economical resources and distribution, human resources (including access to labor) etc. Population should not only consider number of persons and population growth, but also distribution of population and the special problems of urbanization (including condensation and squatter areas).

Other factors as social and cultural barriers, acceptance, gender perspectives, ownership of facilities, willingness to pay by consumers, administrative and operational competency often have a higher influence on decision making on water and sanitation systems than the technical aspects. The key role of technological development is that it may solve many problems simultaneously as reduction of costs to reach certain targets, savings in other needed resources and reduction of harmful emissions. In this way technological development may also have a positive indirect effect on other issues as reduction of different barriers, social acceptance and willingness to pay.

BASIC RELATIONSHIPS BETWEEN NATURAL SCIENCE, TECHNICAL DEVELOPMENT AND SUSTAINABILITY

Natural science and technology is only a part of the general problem to reach sustainability in water and wastewater handling, solid waste handling and energy production. However, some basic rules related to natural science and technology must be followed to reach sustainability and have its roots in thermodynamics including material and energy conservation and transformations and entropy as a fundamental concept and its relationship to information theory and biodiversity.

Elements as nitrogen, phosphorus, carbon and sulfur are conserved and the purpose of treatment technologies is to transfer compounds of the elements in polluted streams that either do not harm nature (as nitrogen gas) or may be used as a resource (as methane gas and nutrients). Energy savings and recovery are important issues for sustainability for instance related to emissions (as carbon dioxide) and resources depletion (oil, coal, etc). Sustainable development coupled with treatment technologies of water, wastewater and wastes or with energy production is coupled to material and energy balances with a purpose to minimize pollutant emissions and resources depletion.

Entropy may be defined as “the order in nature” with a direction towards less order in a system and is used for instance in design of heating and cooling facilities. The statistical definition of entropy has similar mathematics as used in information technology or description of biodiversity. Advantages and disadvantages of specialization versus diversity in systems with water, wastewater,

solid wastes and energy production have an analogy with the entropy concept. Different aspects on specialization versus diversity are:

- Concentration and dispersion steps. Material flow in society has a general function of concentration and dispersion steps. This may be exemplified by taking up diluted resources from mines and concentration of them in different products (as a certain metal), the materials in the products are after use dispersed as a mixture of materials into solid wastes or in a wastewater flow. In a subsequent treatment step a certain material or compound may be concentrated as in central sorting of materials or transfer of pollutants and resources in wastewater into sludge. Further treatment often means dispersion as emissions of rest products into the atmosphere (including efficient dispersion facilities (as chimneys) or outlet pipes into a recipient. The solid phase can cause a dispersion of materials as leakage from sludge or ashes deposited on a landfill. Landfill leachate transported to a wastewater treatment plant may mean recycling of a pollutant into sludge that again is transported to the landfill. Much attention must, thus, be attended to policies and methods that are not based on transformation of pollutants to another phase giving pollution to the original phase.
- Sorting of streams. A way to diminish the number of sequences of dispersion/concentration of materials is to sort waste streams and handle them separately near the source. This means minimizing of mixing of different waters to a combined stream as in an industry (process waters, cooling water, storm water, sanitary water, etc) before possible reuse and recycling. The same approach may be used for wastewater streams in households (urine, toilet wastes, grey water (waters from bath, kitchen, dishing), drainage water, etc. Separate handling of sorted and separated streams mean improved possibilities to recycle materials and energy and possibilities to improve treatment efficiencies. However, sorting and separation also mean a need for sorting facilities (inside buildings or locally), storage, and transport (for instance pipes for transport of urine, toilet water, grey water, storm water, etc). These investments may cause environmental emissions and resources depletion. Secondary effects on environment emissions and resources depletion due to investments in sorting facilities, storage tanks, separate pipes, etc counteracts benefits of sorting and may make this approach unsuitable in several applications.
- Merging. Companies often merge when they have the same products and customers and also when the costumers and products are different, but complementary. Economical incentives are reduction of costs of production due to more efficient use of equipment and by cutting of redundancy costs and may thereby increase shareholders value. Integration of solid waste, water, wastewater and energy processes at the municipal or regional level is therefore an interesting option for companies. Similar technologies are used for treating water, wastewater and solid wastes (including those originating form energy processes). The treatment processes requires energy with a need for energy savings but may also produce energy as methane gas, electricity (from incineration processes) or heat (from heating pumps or from incineration). Similar laboratory tests are used, consumers are often the same and integration to larger units give the possibilities to employ qualified staff. On the other hand, increased cost-efficiency can also be obtained by higher specialization. Delegation of the responsibility for handling of different waste streams (as disposal of produced sludge) to different private highly specialized companies is an interesting option.
- Decision making. Specialization and diversity are also important aspects in decision making. Much attention is today given on methods to broaden decision making not only to include experts and employees, but also to encourage consumers, NGOs, stakeholders, etc to be involved in the decision procedure.

MUNICIPAL ECOLOGY AS A POSSIBILITY

Municipal ecology related to water, wastewater, waste and energy has similarities with ecology in nature with its material end energy flows and also to approaches such as “Engineering ecology”, “Industrial ecology” and “Rural ecology”. As a general idea most of the materials should recycle in the municipality with little use of energy. The use of water should not decrease the ground water level in the surroundings and mineral and non-renewable energy use should be minimized. Changes in policy are illustrated in Figure 1:

- During the starting period of industrialization and urbanization resources were taken from rural areas and pollutants from different activities were discharged to the surroundings and also inside the urban area giving rise to polluted soils and sediments (Figure 1a)
- Due to environmental effects on the surroundings different external treatment methods (“end-of-pipe”) were introduced to remove pollutants from air and water with a certain transfer of pollutants into a solid phase that after treatment was disposed for instance on a landfill which may be a secondary pollutant source (Figure 1b)
- As a result of sustainability constraints it is necessary to enforce (Figure 1c):
 - Internal recycling of materials in the urban area
 - Transformation of used material into products or raw materials for internal or external use outside the specific urban area
 - Restoration of earlier polluted soil and sediments for renewing resources as areas for building and lakes for recreation etc.

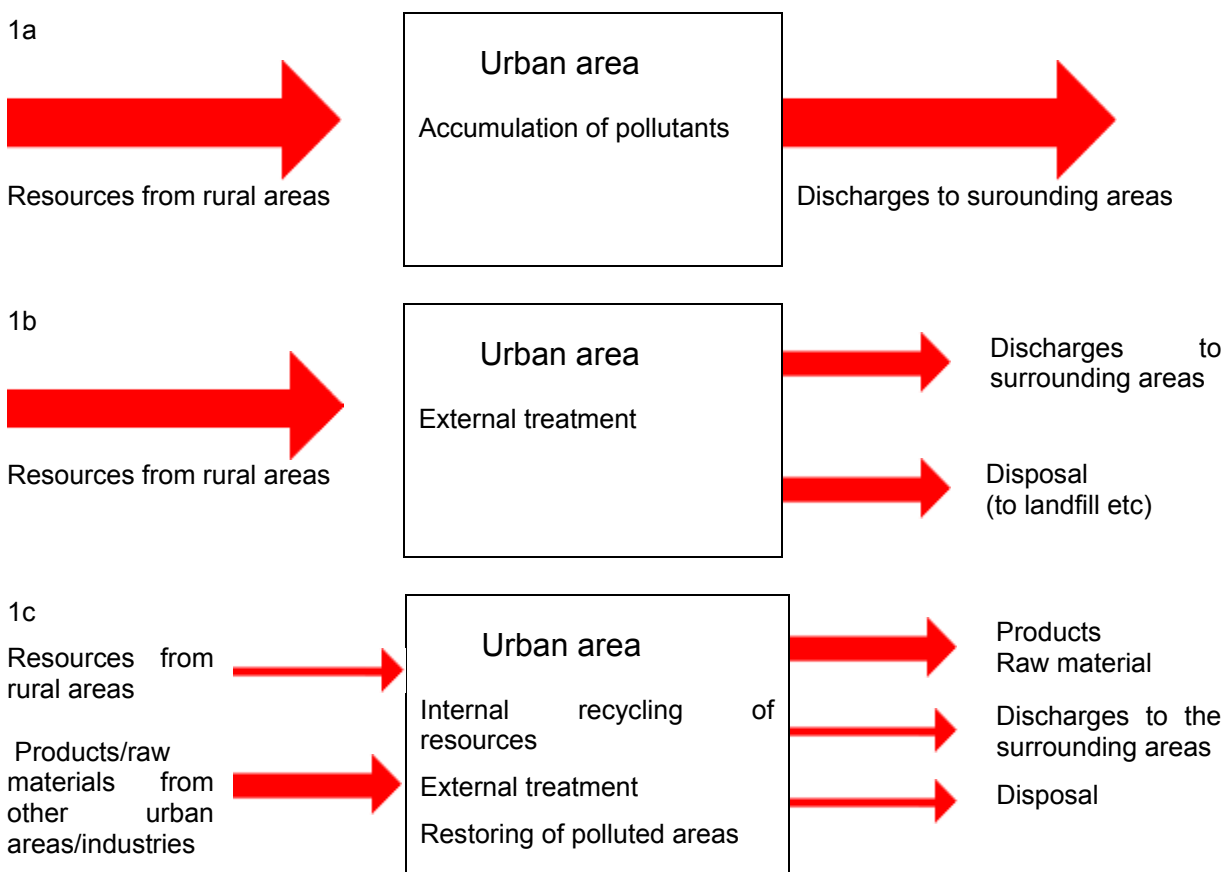


Figure 1. Principle schemes of resources depletion and environmental emissions without internal or external measures (Figure 1a), resources depletion and environmental emissions with “end-of-pipe” treatment (Figure 1b) and present requirements related to sustainability (Figure 1c).

Eco-cycling within a municipality means that materials earlier seen as a pollutant should be recycled or used as a resource in next activity with a material flow with similarities to the food web and chains in a natural eco-system. Only a small fraction of materials transported into a municipality should be deposited, while the main part should be used for recycling or upgraded into new products or as raw material. Energy consumption should be minimized and the energy content in waste streams should be recovered.

Water handling in a municipality or a river basin should secure that water entering the area (rain water, surface water, ground water) will have equal or better quality than the water leaving the area. In this respect water entering the area can be seen as a “loan” that after use and treatment is returned back to nature. The “loan” does not mean that the water composition should be exactly the same for water entering and leaving the area. Instead, pollutants (heavy metals, pathogens and organic micro-pollutants) may be reduced during use and treatment of water, an alkalinity increase during use and treatment may be beneficial in discharge into an acidified recipient, and increase of nutrients in the water during use and treatment may be valuable in combined irrigation and fertilization. An urban area may not in the future export pollutants to the surroundings, but instead be a pollutant sink.

Water and waste handling are only parts in an ecological society and interactions with other activities are necessary to consider. Life Cycle Assessment (LCA) means evaluation of environmental effects concerning “from the cradle to the grave” of a process, product or activity with respect to the use of natural resources and emissions of pollutants based on material and energy balances. Tools are, thus, available or in a development stage to assess different routes to accomplish water and waste handling as a part in “municipal ecology”.

Water and waste transport and treatment can be seen as a “middle function” between “inputs” from different activities in society and “outputs” including the general functions of demands by consumers, but also indirect effects related to depletion of natural resources and emissions to the environment.

“Inputs” are related to consumer behaviour including type of food intake, source control, and wastes from different activities. “Soft sciences” are much related to this area but also many technological aspects as water and waste facilities inside houses, water savings and separation in industries, and type of water and sewer nets.

“Outputs” from water and waste handling systems are also influenced by legal and economical incentives. Due to political priorities and/or market considerations (including “green taxes”) much attention is today given to water (use for irrigation, ground water conservation, for ponds and in fountains, uses in industry and for possible water supply in municipalities), the water content of nutrients (for direct use in agriculture or production of fertilizers etc), energy recovery (heat in wastewater and biogas production, etc), organic compounds in sludge (compost, use for landfill cover etc), inorganic compounds (sand, use in road building or in cement industry, etc) and many different possibilities of production of special products (including activated carbon and metal recovery). Solid waste management with a purpose for recycling and use of products and materials is more and more promoted in society with legal constraints and economical incentives.

JOINT POLISH-SWEDISH RESEARCH CO-OPERATION – FROM SPEZIALIZATION TO INTEGRATION

The joint Polish-Swedish research co-operation had as a starting point a specialization on “Advanced wastewater treatment” between 1995-1998 with the Div. of Water Resources Engineering, KTH, in Stockholm and Inst. of Water Supply and Environmental Protection, Cracow University of Technology, as main participants. As advanced wastewater treatment in many aspects means separation of water resources and pollutants into a sludge phase and together with the connection with solid wastes it was logical to formulate a new co-operation project on “Product and energy from wastewater sludge and organic wastes” between 1998 and 2001. The co-operation was extended with the Institute of Heat Engineering and Air Protection”, Cracow University of Technology.

It was recognized that most technical universities around the world today include environment and resources engineering as a special direction in their education and research activities. Many advantages can be obtained by sharing experiences from education (including course materials) and on published and on-going research activities and plans for the future. It was therefore natural to expand the scope of the co-operation project to cover “Integration and optimization of urban sanitation systems”. The co-operation project was extended with the Institute of Engineering and Environmental Protection, Technical University of Bielsko-Biala, Center for Environmental Studies, Gdansk, and Environmental Biotechnology Department, Silesian University of Technology.

Specialization versus integration should not be seen in conflict with each other, as both are equally important. Many specialized studies have been reported within the joint Polish-Swedish research co-operation project for instance on nutrient removal and sludge handling. However, the specialized knowledge must be integrated with specialized knowledge from other fields and in an overall goal to reach a sustainable society.

Published results both on specialized and integrated issues on water, wastewater and solid waste handling are shown on <http://www.lwr.kth.se/English/Projects/Index.htm>.

CONCLUSIONS

A joint Swedish-Polish research co-operation was started about ten years ago with support from the Swedish Institute (SI). The project started with a focus on advanced wastewater treatment followed by cooperation on product and energy recovery from wastewater sludge and organic wastes and at present on integration and optimization of sanitation systems in urban areas. Although specialization and integration have equal importance to reach sustainability the general focus changed from specialization to integration as integration aspects were judged to be a less understood issue to reach sustainability.

Integration of water, wastewater and waste handling may be seen as a part in “municipal ecology” with an analogy to ecology in nature with its material and energy flows. Some advantages of increased integration include combinations with the energy sector (biogas, district heating), improved technical functions, possibilities in a large organization to employ qualified staff, simplification of fee collection system, and less environmental emissions and resources depletion.

