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WATER MANAGEMENT IN *RECYCLING SOCIETIES* PART II. SANITATION, MANAGEMENT OF RESIDUALS AND BIOCONVERSION

Present shape of urban drainage and sanitation, management of residuals, bioconversion facilities in developed world emerged in a long process of development, mainly in European countries and in North America during the last century. At the time, objectives aimed at constructing these facilities were basically different from what we consider as a main objective today. Since the sphere of our interest in sustainability has changed over from a single human settlement to the whole planet, these facilities should provide sustainable solution for a much larger space and time than before. Departing from our present social objectives and understanding of the connections between human actions and environmental responses, we realize that, in spite of large investments, traditional technologies are not functioning satisfactorily in a global environmental sense. Cities of industrialized countries still contribute to permanent degradation of environment. We realize that even the most advanced wastewater treatment facilities do not solve the problems of open flows of materia and energy. Large-scale *end-of-pipe* wastewater treatment facilities serve as spectacular example of technology that must be changed in order to provide sustainable, global solution. This present paper, in which the rules of preventive approach and novel technology are presented, may constitute a practical way of implementing such an approach. Current and emerging challenges are discussed.

1. INTRODUCTION

Natural ecosystems are self-organizing structures. Self-organization is due to constant change, response and adaptation to the changes in environment. The complexity and diversity is a crucial condition for maintaining this ability. According to PRIGOGINE and STENGERS [1] they may *swim against the tide of entropy and create order out of chaos,* because they form together a structure that is open in terms of

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energy, while cycles of materia are closed. Plants, bacteria, algae and animals play a very important role by regulating, adjusting and adapting the system. Global mass-balancing processes such as regulation of the level of carbon dioxide and other gases in the atmosphere, ion exchange, decomposition of toxins, as well as thousands of other chemical reactions are carried out just in right proportions and with the efficiency and accuracy that are higher than those of any human-designed machinery. These invisible and free-of-charge actions taking place in natural ecosystems are *responsible* for present chemical composition of atmosphere and soil, natural water cycle and present climate.

2. SANITATION

Sanitation solutions and related infrastructure present in highly developed countries may be inadequate to accomplish new goals of modern societies in which recycling of materials has an important role to play. Present water sanitation solutions allow us to produce the wastewater that is wasted water. The world can neither waste water any more nor loose nutrients present in wastewater. Large streams of wastewater from present cities contain organic material that in a *recycling society* should be used for food production instead of being wasted in treatment plants or released to environment without treatment. The ways of recovering nutrients suitable for agriculture, instead of using finite and soil-polluting fertilizers, must be rapidly found and implemented [2].

Considering the above statements, it seems that *present water management methods, sanitation and wastewater treatment technology known in developed countries become outdated and, thus, should not be uncritically implemented in developing world, because they cannot provide solution to the recycling targets of today*. It is worth stressing that in 1996, 95% of wastewater all over the world was discharged into environment without any treatment. Today, totally ca 3 billion people lack sanitation. If sanitation provision continues in the future as it did in the past, up to 5.5 billion people will be without sanitation by the year 2035. Many of these people will be living in overpopulated urban settlements. According to the WHO statistics [2] from the year 1996, 3.3 million people died annually from diarrhoeal diseases, and 3.5 billion were infected due to a lack of adequate and affordable sanitation solutions. *High cost of water-borne sanitation solutions was chiefly responsible for this situation*. The necessary investments in water and sanitation are far beyond the economical potential of the majority of countries and international funding organizations. Full coverage of sanitation combined with high level of wastewater treatment is possible only in rich countries and serves only about 6% of the world population. It is achieved on cost of excessive use of natural resources putting the global resource security in danger.

According to the World Bank statistics, about 94% of people in the world lack proper sanitation, and 96% of world population have no access to wastewater treatment facilities. A great majority of people that have access to sanitation use on-site sanitation lacking water for disposal of effluents. In many areas, the on-site sanitation solutions contribute to serious pollution of groundwater as, for example, is the case of Dar es Salaam in Tanzania [2]. However, even several European countries do not have full coverage of wastewater treatment plants: for example, in 1995, in Belgium only 52% of sewage was treated. In Canada, 66% of wastewater is treated, while in Latin America – only 2% [3]. In former Eastern Europe, the situation is not better. Unfortunately, present sanitation and wastewater management systems, even fully implemented, are inefficient, hence they do not provide full and safe recycling of anthropogenic nutrients. Therefore such nutrients cannot be used for agricultural food production.

3. FUTURE OF SANITATION

An attempt to develop sanitation infrastructure with recycling ability is pronounced in construction of composting or urine separation toilets. Urine separating methods, i.e. safe recycling of sanitary nutrients, should be profitable, which means that environmental costs of processing and transporting residuals to agricultural area will not exceed economical and environmental benefits. The distance between the area where urine is collected and the place of its use is crucial for economical outcome of technology using urine as fertilizer. Energy use and environmental pollution due to transportation of urine result in environmental and economical risks that should be evaluated before the decision about the type of sanitation is taken. Safe recycling of human nutrients in such a way as to make them useful to agricultural production requires a lot of infrastructural changes, including development of new systems for transportation of urine. In such systems, environmental damage should not exceed environmental benefits. However, a lot is at stake because human urine is a good fertilizer. Urine that one person gets rid of yearly contains 5.6 kg of nitrogen, 0.5 kg of phosphorous, 1.0 kg of potassium. Proportions between these nutrients are very similar to those in many commercial fertilizers [2], [4], [5], [6]. In future *recycling societies*, all available nutrients should be used for food production instead of being wasted in wastewater treatment sludge.

Facing repeatedly occurring malnutrition in developing countries, it may be educative to notice that waste matter excreted by one person yearly is just enough to produce such amount of grain that is sufficient to cover nutrition need of one person yearly [2]. In many European countries, separating toilets are installed in increasing number of buildings both in normal single-family houses and in large public buildings. Because houses equipped with separation sanitation do not need to be connected to the treatment plant, less treatment plants can be built in the future [7]. This may bring about economic benefits. Recent developments in sanitation are clearly oriented towards establishment of *recycling societies*.

On a global scale, the *global* change in the approach to sanitation solutions and advanced technology are necessary. New developments in the so-called *ecological sanitation* solutions pave the way for recycling of human residuals without a health risk (see also *Ecological Sanitation* by Steven A. Esrey, Jean Gough, Dave Rapaport, Ron Sawyer, Mayling Simpson-Hébert, Jorge Vargas, Uno Winblad (editor), published by Sida, 1998 – [8]). New residential housing equipped with alternative sanitation function, usually problem-free, are readily accepted by society.

Centralized water-born sanitation, together with wastewater pipe systems and *end-of-pipe* treatment plants, demonstrates a remarkable ability to minimize a health risk. Another primary function of these systems, i.e. protection of the natural environment against pollution and bacterial contamination, is considered to be performed satisfactorily, but there is impressing evidence that many potentially dangerous *chemicals found in surface- and groundwater may not be eliminated even in multi-stage treatment plants*. Major long-term problem connected with this technology is that it is resource-intensive in terms of used natural resources bound in wastewater pipes and treatment plants. The ability to create sustainable closed material flows characterising a *recycling society* is hampered due to mixing of useful and harmful elements.

Taking into account the present dynamic changes in technologies applied in water and wastewater sector, an increasing number of experimental solutions in water supply, sanitation and in other water-related technologies is to be expected in a near future. Such changes and technological development are driven not only by scientists and idealism of population, but also, in some countries, by administration and politicians. In such a climate, research institutions feel free to make more experiments with new type of water-related infrastructure and new forms of living for inhabitants. This brings about hope for the development of a new future *recycling society*.

4. MANAGEMENT OF RESIDUALS

Some part of organic liquid impurities from our households may, after treatment, be relatively safely discharged into the rivers and the sea where marine organisms can uptake them. However, if the level of such material increases enormously, it may result in unwanted changes in marine biosystems which manifest themselves in algal blooms and other unfavourable influence on the marine environment. Another part of organic residuals may be also relatively safely deposited on waste deposit sites and, by transformation to gases, partially used as a source of energy. However, disposal of non-organic wastes such as metals and other non-soluble wastes pose considerable problems. Metals built in numerous industrial products and goods may corrode and, sooner or later, enter terrestrial and aquatic environments. Some of these metals are harmful to natural environment and, if discharged into the soil, they change its physical and chemical characteristics making agriculture products harmful to our health. Of a large number of such harmful residuals some are well known and discussed in scientific debate. Thousands of other substances and their long-term human and environmental effects are unknown. *Cadmium* is one of those substances that are relatively well known and recently discussed in scientific context. Some researchers also consider it as one of the most serious threats for human health [9]. Permissible levels of some substances in sludge are established, but for the majority of other substances, such as flame-protective chemicals, drugs, antibiotics, hormone-similar substances, bromines, dioxins, furans, PCB and others there are neither standards nor information about their potential toxicity and accumulation.

All above-mentioned and other persistent hazardous substances found in sewerage sludge will, sooner or later, enter surface water bodies and groundwater. These substances may also be accumulated in agricultural products. In the late 99-ties, hormonal substances were found in many rivers and lakes in the country. None can say what the long-term ecological effects and the influence on human health will be. In conclusion, as yet there are no risk-proof methods of handling and use of wastewater sludge. Incineration, deposition, pelleting, and other methods that are coming, will anyway, sooner or later, enable potentially harmful substances to enter ecological systems, and later on, human bodies. However, perhaps the gross error, or at least a bottleneck of present water and sewerage systems, including water sanitation, is that these systems have no ability to recycle safely organic residuals from human settlements in such a way as to make them useful to agriculture.

The use of agricultural fertilizers results in pollution of agricultural soils with cadmium. For example, in the 19th century, due to pollution of Swedish agricultural soil with cadmium, the content of this element in the seeds of wheat increased by 30% and doubled in kidneys of Swedish pigs. In human kidneys, it increases by 2% per year [9].

Increased incineration of solid wastes results in environmental risks due to emission of gases. Such gases from incineration plants contain several potentially risky residuals that are deposited on land. In smoke, the following pollutants are emitted: CO, CO_2, SO, SO_2, FO_2, heavy metals, different acids, hydrogen-fluors, etc. *Incineration technology of dealing with organic residuals cannot be applied in a recycling society.*

5. BIOCONVERSION

Instead of being the sources of pollution, all organic wastes and old waste deposits may become a source of renewable energy and substances that can be recycled. In principle, all organic materials that are used by society and come from agriculture, forestry and, to a minor degree, from the natural fossil deposits may be utilized due to a new type of management, called *bioconversion*, i.e. biochemical processes allowing circular material flows which are driven by solar energy bound in plants. In a bioconversion process, plants and other organic residuals can be composted producing fertilizers and biogas.

Traditional composting is rather primitive example of bioconversion, because it usually produces a poor-quality compost, and the by-product, the biogas, is usually not captured at all. The process put in motion in order to maximize biodigesiton, to utilize organic residuals and to produce biogases is more efficient. Bioconversion may be finely tuned to maximal outputs. Based on a current knowledge of biology, chemistry and related technologies, it should be possible to convert all organic materials present in solid wastes and agricultural residuals to biogas and plant fertilizers. Bioconversion belongs to the future, and development of its enormous potential will require new thinking, new research and, finally, new developments in infrastructure. This technology will constitute a substantial contribution to establishment of *recycling societies*.

The Director General of FAO has recently stressed that we face the shortage of food, especially in densely populated rural areas of developing countries. He has stated that we should search for new sources of food. There are about 9000 million ha of land all over the world. Nearly 50% of this area is covered with forests and shrubs, another 35% with pastures and grassland, and only 15% is arable land. Of the products grown on arable land, by far the major part is discarded as residual [10]. This means that approximately 95% of the land areas can be a source of nutrients yet untapped in the sense that their agricultural residuals are not being utilized directly for human consumption. Food science and technology at present concentrate mainly on the 5% of the annual production of potential nutrients that can be used after relatively simple forms of processing, such as cooking and baking. The remaining 95% of residual needs considerable processing using physical and chemical processes or bioconversion before it can be turned into suitable feed or food. In developing countries, the future food production depends, to a high degree, on the conversion of residuals to food products. Thus, the dignity of bioconversion issue is so high that it may be seen as a possible major tool to eliminate risk of hunger and its consequences in developing countries. The solid waste management becomes more a question of recycling nutrients and recovering energy than collection and disposal of solid waste. Instead of posing problems and polluting environment, the end products may be used in agriculture. Bioconversion may become the most important technology to deal with organic residuals in a *recycling society*.

6. CONCLUSIONS

Large streams of wastewater from cities contain organic material that in a *recycling society* should be used for food production instead of being wasted by treatment plants or released to environment without treatment which causes pollution of all sources of water. The ways of returning nutrients to soil, instead of using finite and soil-polluting fertilizers, must be rapidly found and implemented.

Present water management methods, sanitation and wastewater treatment technology known from developed countries become out-of-date and, thus, should not be uncritically used in developing countries, because they cannot provide solution to the *recycling society* of today.

According to the World Bank statistics, about 94% of people in the world lack proper sanitation, and 96% of the world population have no access to wastewater treatment facilities.

Establishment of *recycling socities* requires development of new sanitation systems allowing us to recycle safely wastewater nutrients. Such nutrients can be used in agriculture.

An attempt to develop sanitation infrastructure possessing the recycling ability is succeeded in construction of composting or urine separation toilets.

Safe recycling of nutrients present in human faeces and urine requires a lot of infrastructural changes, including development of new systems for transportation of urine to arable area in such a way that environmental damage will not exceed environmental benefits.

Because the houses equipped with separation sanitation do not need to be connected to the treatment plant, less treatment plants can be built in the future. This may bring about economic benefits. Recent developments in sanitation are clearly oriented towards establishment of *recycling societies*. On a global scale, the global change in the approach to sanitation solutions and advanced technology are necessary.

They are no risk-proof methods of handling and use of wastewater sludge. Incineration technology of dealing with organic residuals cannot be applied in a recycling society.

Instead of being the sources of pollution, all organic wastes and old waste deposits may become a source of renewable energy and substances that can be recycled. In principle, all organic materials that are used by society and come from agriculture, forestry and, to a minor degree, from the natural fossil deposits may be utilized due to a new type of management, called *bioconversion*, i.e. biochemical processes enabling circular material flows, which are driven by solar energy bound in plants.

Traditional composting is rather primitive example of bioconversion, because it usually produces a poor-quality compost, and the by-product, the biogas, is usually not captured at all. The process allowing maximization of bio-digesiton and utilization of organic residuals and production of biogases is more efficient. Bioconversion processes may be finely tuned to maximal outputs. Based on a current knowledge of biology, chemistry and related technologies, it should be possible to convert all organic materials present in solid wastes and agricultural residuals to biogas and plant fertilizers.

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GOSPODARKA WODNA W ROZWOJU ZRÓWNOWAŻONYM CZĘŚĆ II. SYSTEM SANITARNY, ZAGOSPODAROWANIE ODPADÓW I BIOKONWERSJA

Dążąc do zapewnienia rozwoju zrównoważonego, tj. harmonijnego rozwoju społeczno-gospodarczego, należy tak zmienić świadomość społeczeństw, aby funkcjonowały one dzięki maksymalnemu recyklingowi zasobów naturalnych. Podstawowymi elementami, na których opiera się takie społeczeństwo, są: odpowiednie systemy sanitarne, gospodarka osadami i biokonwersja. Aktualnie systemy sanitarne w miastach wytwarzają ścieki, które nie nadają się do wtórnego wykorzystania. Ścieki te zawierają ogromne ilości substancji organicznych. W społeczeństwach stosujących zasady rozwoju zrównoważonego substancje te, zamiast zanieczyszczać środowisko, są wykorzystywane w produkcji żywności. Dlatego też rozwój zrównoważony wiąże się ściśle z tworzeniem zasadniczo nowych modeli i rozwiązań technicznych. Nowe podejście dotyczy także problemu stale narastających ilości odpadów stałych, które są rozpatrywane nie jako źródło zanieczyszczenia i zagrożenia dla środowiska, ale jako źródło odnawialnej energii i cennych surowców. Wszystkie materiały organiczne, stosowane i używane przez społeczeństwo, mogą być utylizowane dzięki nowej metodzie gospodarowania odpadami, zwanej biokonwersją.