Wastewater, 1. Introduction

Walter Simmler, Bayer AG, Leverkusen, Germany

1. General Survey

As mankind eventually adopted a more settled, non-nomadic way of life, people became increasingly involved in the technical aspects of water. To a large extent, the primary concerns in the beginning were utilization and improvement of existing water resources, together with protection against the hazards and potential harm associated with uncontrolled natural water. It was only toward the end of the nineteenth century that wastewater became an issue in science, technology, and legislation: specifically, its production and treatment, in terms of both municipal and industrial sources [1, 2].

As early as 4500 years ago the first prerequisites were met for urban and agricultural water management. This occurred in the Indus Valley, and it encompassed irrigation and drainage systems, canals, and sewage facilities. Even so, the treatment of wastewater in formal waste-treatment plants by means of the microbial degradation of wastewater components was reported for the first time in 1892 in London, followed in 1895 by similar efforts in Frankfurt/Main. In both cases it was municipal wastewater, including that from artisans, craftsmen, and small factories, typical of larger cities of that time. Already in the Middle Ages communal wastewater from Milan was being used directly to irrigate the meadows along the outskirts of town. Much earlier, in Greco – Roman times, extensive facilities were erected and maintained for supplying drinking water to cities. Wastewater in those days presented no major problems, and sewage systems were regarded less as a means of collecting water for reuse than as a way of draining off potential sources of hazard and preventing pollution of the streets, with the attendant risk of a spread of vermin and epidemics.

Development of the organized utilization of water as an essential resource for human beings, animals, and plants led to further technical strides, such as dams against flooding or for storage purposes, waterways designed for transport, and harbors on the seacoast and along inland waterways. Problems of wastewater arose gradually during the same period in conjunction with the increase in urban population as the natural self-purification capacity of surface waters proved no longer able to keep pace with development. Risks related to groundwater contamination are associated not only with emissions in the form of wastewater; the ground – air cycle plays a role as well via atmospheric deposition [3]. The state of a particular body of water can be described by a set of code numbers, but the core of the problem is in fact a sum of all the processes leading to the observed state. In this case, the essential element is the kinetics of two opposing processes: the rate of pollution, and the rate of cleansing. Each of these is in turn a combination of natural and anthropogenic phenomena applicable to the site in question. Most of the problems are derived not from absolute numbers, but rather from population densities, production densities, productivities, etc., in the various urban centers of the industrialized world, all of which actually have access to an adequate supply of natural water.

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Utilization of water power generated by falls, tides, or waves, and then transformed into the power of mills, pumping plants, and turbines, has been responsible for very little of the wastewater problem, which in the early days of industrialization was due largely to hammer and stamping mills in the metalworking industry and various ore-dressing facilities. Only when the use of water led to its exploitation as a production medium the greatest specific wastewater load was reached. This was especially the case with process wastewater derived from tanneries and dye works. To this day, street names associated with these activities can be found along inner-city watercourses in the old city centers of such medieval towns as Nuremberg and Strasbourg.

High densities of population and industry – as in the Ruhr area of Germany during the nineteenth century – necessitated the development of a complex water economy. Thus, the Ruhr – Emscher water system provided simultaneously for drinking water, industrial water, and inland waterways, and it even included a wastewater disposition system fully consistent with the knowledge and technological potential available at that time.

In the terminology of water economics, *consumption* of water refers to a loss of quantity, not a decrease in quality. In this sense, consumption represents that part of the water supply that is lost in the course of use, primarily through evaporation. This fraction of the water is permanently withdrawn – at least from the local water cycles – and is thus no longer available for further utilization, so it must be replenished with water from precipitation, springs, or wells [2, 3].

As industrialization proceeded, two unique characteristics of water acquired rapidly increasing importance: its high specific heat capacity, and its rather high solvent power with respect to many inorganic and some organic substances. The consequences of these factors in the context of the production and disposal of wastewater are quite different, however. Water that is intended to serve as a heat reservoir, cooling agent, steam source, etc., must be cleaned before use in order to prevent corrosion and erosion in turbines and heat exchangers, and it is subsequently returned to the environment in a purified state, albeit at a higher temperature. On the other hand, water in its function as a reaction medium, or even a reaction partner, has now developed into the most significant source of wastewater in industry. Entire branches of manufacturing are based on production processes carried out in the aqueous phase, where water is used as a solvent, dispersing agent, transport medium, and reagent. This is perhaps most evident in the case of breweries, in sugar, paper, and pulp factories, in dye manufacture by chemical concerns, and in dye works, tanneries, and the like where the real problem is one not only of the actual content of the wastewater, but also its quantity [1, 4].

For the year 2000, a global balance of quantities and fluxes shows an overall water supply of 25 000 km^3 and a water demand of 6000 km^3, representing 24 % of the directly usable supply [1]. When this is allocated among the major consumers and account is taken of the corresponding levels of specific water consumption (as defined above; i.e., evaporation), several trends with regard to quantities and types of waste water are discernible:

Consumption category	Percentage of total demand (6000 km^3)	Consumption (evaporation) as a percentage of demand
Domestic	8	20 – 30
Industry	29	15 – 20
Agriculture	59	75
Storage losses	4	100

Water circulation through the atmosphere occurs relatively rapidly. The atmosphere contains 13 000 km^3 (ca. 0.02 %) of the overall (liquid) global water reserve of 1.3×10^9 km^3. The annual quantity subject to evaporation (which is equal to the annual amount of precipitation) is estimated at 475 000 km^3. This corresponds to a 35-fold annual turnover of the atmospheric content, which means water exchange between the atmosphere and the surface of the earth is complete every 9.5 days. In some cases local circumstances lead to considerable deviations from these global values.

Wastewater treatment becomes especially important in times of water scarcity. This is particularly true when agriculture, domestic water needs, and industry find themselves in vigorous competition. The greatest increase by far (Fig. 1) is anticipated for agriculture [1], assuming for the year 2000 a world population of $6 - 6.5\times10^9$.

Water is regarded as the chief raw-material problem of the future, elevating wastewater

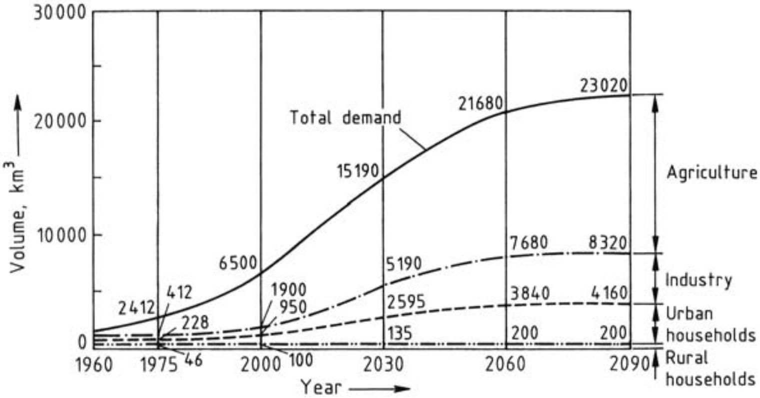

Figure 1. The increasing worldwide demand for water, projected into the future

treatment to the status of a recycling technology. This involves "substance protection" in the sense of sustainable development (→ Sustainability and Industrial Chemistry - Ethical Aspects and Approaches), together with the maintenance of an adequate supply of drinking water, an emphasis that goes beyond the earlier concern directed almost exclusively toward environmental protection, especially the protection of natural waters.

Each of the processes described below has its place in the broad spectrum of technical possibilities. The question of what is the "best process" should thus be replaced by a search for the most suitable process in a particular circumstance, taking fully into account the nature of certain definable problem cases. Modern technological development of wastewater treatment has occurred largely in and with the aid of the chemical industry. However, the wastewater problem and its treatment is of interest not only to this particular aspect of industrialized society. Numerous other branches are affected as well, especially municipalities, often to an even greater extent.

There is no shortage today of diverse international experience in the construction and operation of waste-treatment plants. In fact, in some places this has developed into its own separate branch of process engineering. It is still worth noting with respect to terminology, however, that some of the reasoning applied to wastewater concepts and standards of evaluation has been borrowed from neighboring disciplines, especially limnology and biology.

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References

1 G. Garbrecht: *Wasser*: Vorrat, Bedarf und Nutzung in Geschichte und Gegenwart, Rowohlt, Reinbeck 1985.
2 J. Marcinek, E. Rosenkranz: *Das Wasser der Erde*, Verlag Harri Deutsch, Frankfurt 1989.
3 H. J. Voigt: *Hydro-Geo-Chemie*, Springer Verlag, Berlin 1990.
4 Umweltbereich Wasser, Fonds der Chemischen Industrie, Frankfurt 1992.

Further Reading

W. W. Eckenfelder: "Water, Pollution", *Kirk Othmer Encyclopedia of Chemical Technology*, 5th edition, John Wiley & Sons, Hoboken, NJ, online DOI: 10.1002/0471238961.1615121205031105.a01.

S. Lin, C. C. Lee: *Water and Wastewater Calculations Manual*, 2nd ed., McGraw-Hill, New York 2007.

S. X. Liu: *Food and Agricultural Wastewater Utilization and Treatment*, Blackwell Pub., Ames, IA 2007.

N. L. Nemerow, F. J. Agardy, J. A. Salvato: *Environmental Engineering - Water, Wastewater, Soil and Groundwater Treatment and Remediation*, 6th ed., Wiley, Hoboken, NJ 2009.

J. Robinson: "Water, Industrial Water Treatment", *Kirk Othmer Encyclopedia of Chemical Technology*, 5th edition, John Wiley & Sons, Hoboken, NJ, online DOI: 10.1002/0471238961.0914042118150209.a01.

D. L. Russell: *Practical Wastewater Treatment*, Wiley-Interscience, Hoboken, NJ 2006.

J. E. Singley, J. Robinson: "Water Treatment", *Kirk Othmer Encyclopedia of Chemical Technology*, 5th edition, John Wiley & Sons, Hoboken, NJ, online DOI: 10.1002/0471238961.1321140919091407.a01.pub2.

F. R. Spellman: *Handbook of Water and Wastewater Treatment Plant Operations*, 2nd ed., CRC Press / Taylor & Francis, Boca Raton, FL 2008.

Water Environment Federation: *Operation of Municipal Wastewater Treatment Plants*, 6th ed., WEF Press / McGraw Hill, New York 2008.

U. Wiesmann, S. in Choi, E.-M. Dombrowski: *Fundamentals of Biological Wastewater Treatment*, Wiley-VCH, Weinheim 2007.