Environment Protection Engineering

Vol. 11 1985 No. 3–4

L. A. ALFEROVA*, A. P. NECHAEV*, P. P. MARKOV*

# FUNDAMENTALS OF CREATING CLOSED-LOOP WATER SUPPLY SYSTEMS IN INDUSTRIAL ENTERPRISES

The paper covers the main principals of designing the closed-loops in the industrial water supply systems, the classification of wastewater and the development of schemes for desalination and reuse of brine.

Schemes of wastewater treatment, involving the treatment of both local and combined flows of wastewaters, must be optimal from the engineering and economic standpoint. Hence, the development of mathematical models simplifying the investigations and reducing the time necessary for determinating the optimal schemes and operation parameters of the separate units is of a special importance.

In some instances the construction of closed water supply systems will prove to be more rational in industrial complexes and areas that at individual enterprises.

A number of new problems created by closing the water loops in industry is also discussed.

The protection of natural waters in the Soviet Union becomes more and more significant. In the 10th Five Year Plan 9.3 milliards rubles of capital investment will be spent on environmental protection. In the 1976–1980, the recirculating and subsequent water supply systems of the total capacity of $121.7 \times 10^6$ m$^3$ per day constructed in industrial enterprises led to saving in 1981 more than $40 \times 10^9$ m$^3$ of water from natural water resources. Considering the strict regulation concerning the degree of water treatment, the discharge of raw wastewaters was reduced by 20%. However, water treatment facilities in each industrial enterprise, even in those using modern treatment technology, will not prevent completely the water reservoirs from pollution with wastewaters.

The most rational solution to the problem of water basins protection is the creating of closed-loop water supply systems in industrial enterprises. The systems consist in recirculation of water and the reuse of effluent for technological purpose; fresh water being taken mainly for potable water supply. In order to construct such systems technological processes permitting the maximum use of raw materials, sharp reduction of wastes and

* VNII VODGEO, Moscow, USSR.

the maximum possible reduction of water consumption should be developed. It is also very important to design the rational schemes of industrial water supply involving reuse of water in technological processes and the methods of local treatment of the most polluted wastewaters. In this case it would be possible to reduce substantially the quantity of wastewaters delivered to the treatment facilities located beyond the technological site. These treatment facilities receive wastewaters containing biodegradable component permitting the treated effluent to be reused in the technological and recirculating water supply systems. The construction of the closed-loop water supply systems in industrial enterprises is based on the following principles:

1. Application of technological processes which do not require water or use it in small quantities and which ensure a more complete use of raw materials. Air coolers, dry gas scrubbing methods and the water preparation of raw materials without water should be widely introduced.

Due to air coolers not only large amounts of water can be saved but also the wastewater volume be reduced. So far more than 3000 air cooling apparatuses have been installed in petrochemical and oil-refining industries only. The use of water for gas scrubbing without recovering and utilization of valuable components should be excluded. Dry methods of gas scrubbing applied in the iron and steel industry allowed them to reduce water consumption by 15–20%.

2. The right choice and location of miscellaneous industrial processes in one enterprise which would allow a successive water reuse.

3. Improvement of technological processes in order to reduce the amount of wastewater and its polluting effect. For example, in nitrogen-producing factories a wide-scale introduction of combined technological units involving the use and utilization of reaction heat reduced the specific water consumption in production of ammonia, nitric acid and ammonium nitrate by 67–70%, 90–95% and 67–70%, respectively. Introduction of the one-stage method of divinyl production in petrochemical industry reduced 100 times the amount of wastewaters. In the production of monocorundum the amount of pollutants in wastewaters may be sharply reduced provided that the generated hydrogen sulfide is recovered from gas-vapour mixtures by means of carbonic sorbents used in the melting charge.

Regeneration of waste acid and alkaline solutions may result in a substantial reduction of salts produced in wastewaters during their neutralization.

4. Rational reuse of water in all technological processes and procedures and construction of closed industrial water supply systems. The development of physico-chemical methods for wastewater treatment, providing the reuse of effluents in the same operation, and a rational use of water in the most water-consuming technological processes (such as washing of primary, semi-processed and end-products) are of a special importance.

In this case the tertiary wastewater treatment is not needed, and the removal of waste components, producing a negative effect on the quality of the product to be washed, seems to be quite satisfactory.

For example, an efficient scheme of water use in the synthetic fatty acids production, developed by VNII VODGEO together with the Scientific Research Institute of Surfactants, provides the 180–200 g/dm$^3$ concentration of acids in wastewaters. Treatment of such wastewaters by the azeotropic rectification permits the recovery of commercial low-molecular fatty acids such as formic, acetic, propyonic and butyric acids on the one hand and the reuse of the effluent in the technological process on the other one. Thus, a closed-loop system of technological water supply was based on acid wastewaters. This system increases the output of commercial acids by 12% and reduces COD of the wnstewater entering the biological treatment facilities from 27 to 2 t/day.

Large amounts of wastewaters are collected at the vacuum vaporizers and vacuum distilling apparatuses, where the volatile components are washed out from gases by water in barometric condensers. No doubt that an immediate recovery of these components from gas-vapour mixtures with the help of special adsorbents is much more efficient. For example, according to the principle scheme of the system of primary petroleum refinement installations, hydrogen sulfine discharge into wastewaters and the atmosphere may be substantially reduced and diesel fuel recovery from the barometric wastewaters increased.

5. The classification of wastewaters, according to the character and total amount of pollutants, as well as development of a rational scheme of treatment for their reuse. In this respect the development of methods for the removal of the separate groups of organics, taking account of their physical-chemical properties together with properties of main pollutants occurring in the wastewaters is of a special importance.

For example, according to our classification of wastewaters containing hydrogen sulfide, sulfur alcohols and their salts, organic sulfides and disulfides (resulting from production of sulfate pulp, artificial fibres and monocorundum in the sulfite petroleum refining), all sulfur compounds are divided into two groups, and all wastewaters into three categories. For each category of wastewaters separate methods of treatment were developed, taking into account the nature of pollutants.

6. Nondegradable and toxic compounds of wastewaters, entering the treatment units located outside the technological site, should be removed from local flows prior to their discharge into the column flow.

Economical use of water results in a sharp reduction of the wastewater volume causing an increase in its pollution. Thus, the physico-chemical methods of wastewater treatment have become more widely used.

However, it will be wrong to reject completely the biological wastewater treatment. Each method must be used when any other method is technologically and economically less efficient. The application of one or another method should be proceded by detailed investigations of the nature and physico-chemical properties of wastewaters. Our experience has shown that only a certain combination of methods may be optimal, thus specialists must be good to find for each case the rational method and schemes of wastewater treatment.

7. The quality of biochemically treated effluents should meet both sanitary and toxicological requirements for make-up water in recycling systems of industrial cooling. To this end either one of the methods or their combination may be used. Epidemiological safety of wastewaters is usually achieved by chlorination. Residual chlorine content of 1–1.5 mg/dm$^3$ after a 30 min contact time provides the necessary conditions for disinfection of domestic-fecal sewage. Coli index must not exceed the value of 1000.

Pollution of the atmosphere by treated effluents during the make-up of cooling recycling systems must be eliminated. Water drops splahing out of cooling towers must be the smallest possible and hydro-aerosoles formed must not be toxic.

The conditions under which wastewaters of the city of Moscow can be used throughout and recycling systems of cooling water supply were investigated at the VODGEO Institute. These wastewaters contain 60% of domestic sewages and 40% of industrial wastewaters, mainly from machine-building plants. The investigations have shown that the wastewaters treated according to the following scheme: mechanical treatment — biological treatment — tertiary treatment on grainbed filters — chlorination can be used in through-out waster supply systems. Treated effluents used in recirculating systems of industrial cooling water supply should be conditioned in the following ways: a) when blowing-off is envisaged they are treated in order to protect the systems from biological foulings and carbonaceous deposits: b) when the effluents are used in systems without blowing-off they undergo additional treatment aimed at protection against corrosion. Recycling waters are partially clarified from suspended solids. After such a treatment municipal wastewaters are absolutely safe from the sanitary standpoint and can be reused in water supply and cooling systems of industrial enterprises. Beginning with December 1975, treated sewages of Moscow are used at a number of industrial enterprises in throughout and recirculating water supply systems as well as in a number of technological processes, e.g. in automobile electroplating shops (for washing and stripping, in hydro-wartex apparatus), paint shops (in hydraulic valves of some chambers, phosphatic covering baths), and test shops (in Spriwax chambers, for washing of automobiles and in air-tests).

8. The next principle is an application of watewater desalination. Classification of wastewaters and design of a rational desalination scheme are very important. Removal of individual salts, reuse of treated wastewater and recovered salts, regeneration and reuse of brines — all this serves as an ideal solution of the problem.

Development of analytical methods and investigation of chemical composition of wastewaters at all stages of treatment are of special significance. Investigation of chemical composition of biochemically treated wastewater is the most difficult problem. Information about chemical composition of various industrial effluents permits us to generalize the data and to forecast the quality of treated effluents depending on their initial characteristics and the chosen methods of treatment.

If closed systems of industrial water supply are to be introduced, scientific research should be directed toward the development of water economy systems rather than various treatment methods. This means optimization of water use in all technological processes

and operations, regeneration of wasted solutions, recovery of valuable components from wastewaters, development of the methods of local effluent treatment, introduction of local closed systems of technological water supply, solution of all the problems concerning final treatment of wastewaters, treatment of make-up waters recycling in the systems of industrial cooling, treatment of recycling water, and disinfection of sludge. All these measures will promote the development of industrial water economy systems within a very short period of time.

The problems which cannot be solved now or those solutions which are not optimal can be revealed. In other words, the objects of further investigations concerning the improvements of general technology and treatment technique will be determined.

The problems to be investigated are the following: methods of obtaining highly efficient sorbents for tertiary treatment of wastewaters: choice of effective enzymes for oxidation of wastewater by atmospheric oxygen at temperatures below 250°C; choice of effective enzymes for incineration of wastewater sludges at low temperatures; synthesis of highly effective coagulating and flocculating organic agents; development of new mutatest for toxicological evaluation of the treated effluents and aerosols.

Schemes of wastewater treatment involving treatment of both local and combined flows of wastewaters must be optmial from the engineering and economic standpoints. In this connection the development of mathematical models simplifying scientific research and reducing the time necessary for determination of the optimal schemes and operation parameters of separate units acquires a special significance.

In some cases the design of closed water supply systems in industrial complexes or industrialized areas rather than in individual enterprises will prove to be the most rational. The treatment of wastewaters and final treatment of weakly polluted effluents by hydrobotanical method may appear to be very effective in the south and middle zones of the USSR. This method allows the removal of both organic and inorganic compounds. In the VODGEO Institute the investigations were conducted on the treatment of weakly polluted wastewater discharged from the industrial complex composed of eleven enterprises including a tire plant, an artificial fibres plant and a plant for organic synthesis of synthetic rubber. First step of treatment takes place in a channel where wastewaters come into contact with hydrocultures of higher aquatic plants, at the second step this contact takes place in a pond, where COD of wastewaters is reduced from 90–180 mg/dm$^3$ to 54–86 mg/dm$^3$, $BOD_{20}$ from 25–30 mg/dm$^3$ to 6.5–14 mg/dm$^3$, zinc, copper, methanol, and oil-refinery products (about 50 mg/dm$^3$ in the influent) are completely removed, the removal of aniline, toluene and caprolactan being almost complete.

Aquatic life of hydro-bio-botanical treatment facilities, starting from the channel to the end of the pond, is getting richer and richer, being composed of a great number of hydrobionts, *Daphnia magna* in particular. This increasing growth of hydrobionts indicates that the wastewater toxicity is gradually reduced to the level required for water in sanitary reservoirs.

The quality of treated wastewaters meets that of water used in recirculating systems of cooling water supply.

Thus, in order to introduce closed-loop systems of industrial water supply, a number of new problems must be solved.

## PODSTAWY TWORZENIA ZAMKNIĘTYCH SYSTEMÓW ZAOPATRZENIA W WODĘ W PRZEDSIĘBIORSTWACH PRZEMYSŁOWYCH

Przedstawiono główne zasady projektowania obiegów zamkniętych w przemysłowych systemach zaopatrzenia w wodę, podano klasyfikację ścieków oraz przedstawiono rozwój projektów odsalania i wykorzystania solanek.

Oczyszczanie ścieków, obejmujące zarówno lokalne jak i połączone odpływy ścieków, musi być optymalne z inżynierskiego i ekonomicznego punktu widzenia. Stąd też szczególne znaczenie ma rozwój modeli matematycznych, upraszczających badania i redukujących czas potrzebny do zaprojektowania optymalnych układów i określenia optymalnych parametrów pracy poszczególnych jednostek.

W niektórych przypadkach okaże się, że zamknięte systemy zaopatrzenia w wodę są bardziej racjonalne w kompleksach przemysłowych i na obszarach uprzemysłowionych niż w pojedynczych przedsiębiorstwach.

Przedyskutowano także wiele problemów powstających podczas tworzenia zamkniętych obiegów wody w przemyśle.

## DIE GRUNDLAGEN FÜR DIE SCHAFFUNG VON GESCHLOSSENEN WASSERKREISLÄUFEN IN INDUSTRIEWERKEN

Im Beitrag werden die Grundlagen zur Projektierung von geschlossenen Kreisläufen in industriellen Wasserversorgungssystemen vorgestellt. Weiterhin wird eine Klassifizierung von Abwässern aufgestellt und die Entwicklung von Entwürfen zur Entsalzung und Soleverwertung besprochen.

Eine Abwasserreinigung, ob für einzelne Abflüsse oder für die Mischabwässer muß man technologisch und wirtschaftlich optimal gestalten. Besondere Bedeutung kommt der Entwicklung der mathematischen Methoden zu, da sie zu einer Vereinfachung der Versuche und zur wesentlichen Kürzung der Untersuchungsperiode, die zu optimalen Verfahren und zu optimalen Prozeßparametern führen.

In manchen Fällen wird sich herausstellen, daß die Wirtschaftlichkeit von geschlossenen Wasserkreisläufen in Großindustrienlagen und auf stark industrialisierten Flächen größer ist als in Einzelanlagen

Diskutiert werden auch andere Probleme, die bei der Errichtung von geschlossenen Industrie-Wasser kreisläufen auftreten.

## ОСНОВЫ СОЗДАНИЯ ОБОРОТНОГО ВОДОСНАБЖЕНИЯ НА ПРОМЫШЛЕННЫХ ПРЕДПРИЯТИЯХ

Представлены главные принципы проектирования замкнутых циклов в промышленных системах водоснабжения, дана классификация сточных вод, а также представлено развитие проектов обессоливания и использования соляных источников.

Очистка сточных вод, охватывающая как местные, так и соединённые отводы сточных вод должна быть оптимальной с инженерной и экономической точек зрения. Отсюда особое значение имеет развитие математических моделей, упрощающих исследования и сокращающих время, нужное для запроектирования оптимальных систем и определения оптимальных параметров работы отдельных единиц.

В некоторых случаях окажется, что обратное водоснабжение более рационально использовать в промышленных комплексах и на индустриальных территориях, чем на отдельных предприятиях.

Обсуждены также многие проблемы, возникающие во время сосздания замкнутых циклов воды в промышленности.