# ADVANCED WATER TREATMENT TECHNOLOGIES

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***Abstract***
*Residual water contains a series of pollutants, among which some are removed more or less during the conventional water treatment stages, while others are retained for a very short time or at all in the classical water treatment stations. The serious problems related to water protection led to some severe restrictions regarding the concentration level allowed in the purified effluent discharged in the natural outlets. The present paper briefly presents the advanced water treatment technologies frequently used in our country.*

**Key words:** residual water, purified effluent, conventional sewage, wastewater treatment plants, removing.

## INTRODUCTION

Residual water contains a series of pollutants, among which some are removed more or less during the conventional sewage treatment stages, while others are retained for a very short time or at all in the classical sewage treatment stations.

*Table 1*

Quality restrictions for $CBO_5$ and $O_2$, in surface waters

| Water characteristics | Usage categories | | |
|---|---|---|---|
| | I | II | III |
| $O_2$ , [mgf/dm$^3$], minimum | 6 | 5 | 4 |
| $CBO_5$, [mgf/dm$^3$], maximum | 5 | 7 | 12 |

*Table 2*

Maximum suspension quantities, possibly discharged in outlets, according to the dilution degree

| Usage categories | | | Dillution degrees |
|---|---|---|---|
| I | II | III | |
| Maximum suspension quantities [mgf/dm$^3$] | | | |
| 20 – 40 | 25 – 60 | 30 – 100 | 0 – 20 |
| 40 – 100 | 60 – 150 | 100 – 250 | 20 – 50 |
| 100 – 300 | 150 – 450 | 250 – 750 | 50 – 150 |
| 300 – 1.000 | 450 – 1.500 | 750 – 2.500 | 150 – 500 |

The serious problems related to water protection led to some severe restrictions regarding the concentration level allowed in the purified effluent discharged in the natural outlets, restrictions that are shown in tables 1 and 2 [1, 6, 12].

After being mixed with residual water, the outlet water should have the pH between 6,5 – 9,0.

Identifying the existing pollutants in the mechanic-biologic discharged effluent and the effects they have on the environment is highly important in establishing the advanced treatment methods, in order to obey the quality standards in force.

Table 3 shows the characteristics of residual water treated mechanic-biological, as well as the effects they have on the environment and human health.

*Table 3*

Pollutants typical for residual water treated mechanic-biologic and their effects

| No | Pollutant | Effects |
|---|---|---|
| **1** | Solid suspensions | They can cause sludge deposition or can interact with the outlet. |
| **2** | Biodegradable organic compounds | They can deprive the outlets of oxygen resources. |
| **3** | Nonmetals, metals, organic compounds, halogenated compounds, pesticides, herbicides, insecticides | They are toxic for people (cancerous) and for the aquatic environment. |
| **4** | Volatile organic compounds | They are toxic for people, cancerous. |
| ***NUTRIENTS*** | | |
| **5** | Ammonia | It increases chlorine consumption; it can be turned into nitrates and during the treatment processes it can deprive the resources of oxygen; together with the phosphorous it leads to the development of parasitic aquatic mediums. It is toxic for fish. |
| **6** | Nitrates | It stimulates the development of algae and aquatic mediums. With children, they can cause methemoglobinemia. |
| **7** | Phosphorous | It stimulates the development of algae and aquatic mediums. It interferes with coagulation. |
| ***OTHER INORGANIC SUBSTANCES*** | | |
| **8** | Calcium and magnesium | They increase water hardening and dissolved total solids. |
| **9** | Chlorides | They give water a salty taste. They interfere with agricultural and industrial processes. |
| **10** | Sulphates | Cathartic action |
| ***OTHER ORGANIC SUBSTANCES*** | | |
| **11** | Surfactants | They cause foaming and interfere with coagulation. |

It should be mentioned that the potential effects of residual substances existing in mechanic-biologic effluents can vary significantly. Although solid suspensions and biodegradable organic compounds are retained especially through mechanic-biologic treatment, there are some instances in which extra retaining in imposed. Initially, around mid 60's, nitrogen and phosphorous compounds from residual water discharges have triggered attention due to their effect in accelerating the lakes eutrophication and stimulating the aquatic mediums. At the moment, in the countries where the treatment of residual water is very advanced, controlling the nutrients has become a common technique of residual sewage treatment, especially in the instances of refilling the subterranean water provisions.

*Table 4*

Means of reducing residual pollutants from residual water, through advanced treatment procedures

| No | Objective | Method | Effluent type subjected to advanced treatment |
|---|---|---|---|
| 1 | Suspension retaining | Filtration | EM, EBD |
| | | Screening | EBD |
| 2 | Ammonia oxidation | Nitrification in biological stage | EM, EBD, EBND |
| 3 | Reducing the nitrogen | Nitrification/de-nitrification in biological stage | EM, EBND |
| 4 | Reducing the nitrates | Separate phase of de-nitrification in biological stage | EBND and nitrification |
| 5 | Reducing P biologically | Reducing P at water surface | AUB, EM |
| | | Reducing P at sludge surface | NAR |
| 6 | Biological methods of N and P simultaneous retaining | Reducing P and nitrification/de-nitrification in biological stage | AUB, EM |
| 7 | Reducing N by physical or chemical methods | Flash distillation | EBND |
| | | Chlorination at breakpoint | EBND and filtration |
| | | Ions exchangers | EBND and filtration |
| 8 | Reducing P by chemical addition | Chemical precipitation with metallic salts | AUB, EM, EBND, EBD |
| | | Chemical precipitation with lime | AUB, EM, EBND, EBD |
| 9 | Reducing the toxic organic components and the refractory organic substances | Adsorption on active coal | EBND and filtration |
| | | Activated sludge – powder active coal | EM |
| | | Chemical oxidation | EBND and filtration |
| 10 | Reducing the dissolved inorganic substances | Chemical precipitation | AUB, EM, EBND, EBD |
| | | Ions exchangers | EBND and filtration |
| | | Ultra filtration | EBND and filtration |
| | | Inverted osmosis | EBND and filtration |
| | | Electro dialysis | EBND, filtration and adsorption on coal |
| 11 | Volatile organic compounds | Volatilization and flash distillation with gas | AUB, EM |

EM – effluent of mechanic treatment phase;
EBD – decanted effluent of biological treatment phase;
EBND – non-decanted effluent of biological treatment phase;
AUB – gross residual water;
NAR – recirculated activated sludge.

Nitrifying the residual water is also necessary in many instances for reducing the ammonia toxicity or reducing the impact on the oxygen resources in water courses or estuaries. Beginning with the 80’s, a special attention is paid to nonmetals, metals, organic compounds, halogenated compounds, pesticides, herbicides, insecticides, and volatile organic compounds, all these pollutants being considered toxic for people and aquatic environment [1, 2, 3, 11].

Although in Romania the advanced treatment of residual water has become more important in the last 10 years, in the world, a series of techniques and technologies were researched, in order to insure that a treatment station effluent has characteristics corresponding to the admitted limits established by quality standards. Globally, for over 40 years, a great diversity of treatment technologies were studied, developed and applied for retaining the pollutants from residual water (suspensions, biodegradable organic substances, pathogenic germs, nutrients, organic or inorganic compounds with cancerous, mutagen, teratogenic action or with high toxicity, refractory substances, heavy metals, dissolved inorganic substances).

In table 4 are shown the means of reducing residual pollutants from residual water, through advanced treatment procedures.

*Table 5*

Levels of treatment attained with diverse combinations of procedures and individual operations used for advanced treatment of used water

| No | COMBINATION | EFFLUENT QUALITY | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | susp. (mg/l) | $CBO_5$ (mg/l) | CCO (mg/l) | N total (mg/l) | $N\text{-}NH_3$ (mg/l) | phosphates (mg/l) | turbidity (NTU) |
| a | Activated sludge and filtration on granular environment | 4-6 | <5-10 | 30-70 | 15-35 | 15-25 | 4-10 | 0,3-5 |
| b | Activated sludge and filtration on granular environment and adsorption on coal | < 3 | < 1 | 5-15 | 15-30 | 15-25 | 4-10 | 0,3-3 |
| c | Activated sludge and nitrification in a single phase | 10-25 | 5-15 | 20-45 | 20-30 | 1-5 | 6-10 | 5-15 |
| d | Activated sludge, nitrification and de-nitrif. in separate phases | 10-25 | 5-15 | 20-35 | 5-10 | 1-2 | 6-10 | 5-15 |
| e | Activated sludge and salts addition | 10-20 | 10-20 | 30-70 | 15-30 | 15-25 | < 2 | 5-10 |
| f | Activated sludge, salts addition, nitrification, de-nitrification and filtration | <5-10 | <5-10 | 20-30 | 3-5 | 1-2 | < 1 | 0,3-3 |
| g | Biologic reduction of P at water surface | 10-20 | 5-15 | 20-35 | 15-25 | 5-10 | < 2 | 5-10 |
| h | Biologic reduction of N and P at water surface | < 10 | < 5 | 20-30 | < 5 | < 2 | < 1 | 0,3-3 |

According to the method or the combination of methods chosen, various performances can be obtained regarding the residual pollutants retained during the advanced treatment stage. Table 5 shows the treatment levels (expressed through the concentrations of diverse residual pollutants in the "tertiary" effluent), attained with diverse combinations of procedures and operations used for advanced treatment of residual water.

## PHOSPHORUS REMOVAL FROM RESIDUAL WATERS USING BIOLOGICAL MEANS

Lately, a special attention was paid to procedures for P removal using biological means, as alternative to chemical methods. P is retained in biological phase through incorporating procedures of orthophosphates, polyphosphates, and phosphorous linked organically in cellular tissue [1].

Total quantity of P removed is done according to the decanters produced effectively. P contained in cellular tissue is 5 times lower than N content in tissue.

According to local environment conditions, real P matter is 7 to 3 times lower than N content from cellular tissue. On average, the quantity of P removed during secondary treatment through residual sludge can vary between 10-30% from influent quantity.

By using a biologic procedure for removing P, significant results can be obtained, outside this domain.

The concept of removing P by biologic methods means exposing the microorganisms to alternative anaerobe and aerobe conditions.

Exposition to alternant conditions determines microorganisms overstressing, so that the adsorption quantity exceeds normal levels. P is used not only for survival, synthesis and energy but it is also stored and used afterwards by microorganisms.

Sludge containing p in excess is either residual or removed in the lateral treatment flux (sludge line). Alternative exposition to anaerobe and aerobe conditions can be achieved either on water surface, or in the sludge recirculation process [2].

Specific procedures of biologic treatment used for P removal are:

- A/O procedure – which implies P removal on water surface, in biologic phase;
- PHOSTRIP procedure – implies P removal on sludge surface;
- Sequential tank procedure (B.S.) – used for small quantities of residual water, on condition that is has functional flexibility, it allows retaining N and P.

**A/O procedure** (retaining P on water surface) [1]

A/O procedure (fig. 1) is used for retaining P combined with C oxidation from residual water. It is a biomass system in suspension „single-sludge" (a single tank, so single sludge), which combines consecutive anaerobe and aerobe areas.

For nitrification, the supply can be done by increasing the retention time needed in aerobe area. The sludge deposited is returned in the influent at the end of the tank and mixed with influent residual water.

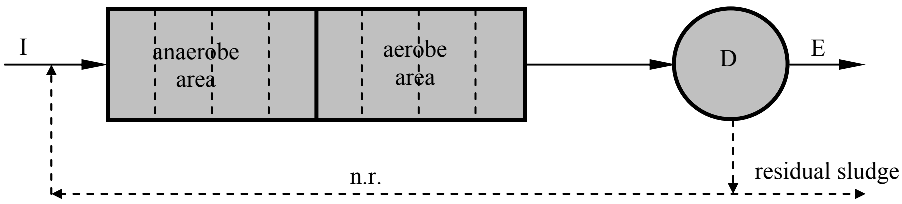


Fig. 1 Technological diagram for A/O procedure:
I – influent; D – decanter; E – effluent; n.r. – recirculation sludge

Under anaerobe conditions, P contained in residual water and in the recirculated cellular mass is released as soluble phosphates. At this stage reducing partially the organic substances (as $CBO_5$) can be done. P is absorbed by the cellular mass in the aerobe area and is retained from fluid flow capacity into the activated sludge. P concentration in the effluent depends greatly on the ratio $CBO_5$ : P of residual water.

For ration higher than 10:1, concentrations of P soluble in the effluent under 1 mg/l can be obtained. When the ratio values are lower than 10:1, metallic salts should be added for obtaining low concentrations of effluent in P.

**Phostrip procedure** (removing P on sludge line) [1]

In this procedure (fig. 2), a part of recirculated activated sludge form biologic treatment is led in an anaerobe tank for P flash distillation. The retention time in this tank generally varies between 8 and 12 hours. P is released in the flash distillation tank, it gets out of the tank as supernatant and the activate sludge poor in P is returned in the aeration tank. Supernatant reach in P is combined with lime or other coagulant in a separate tank and it is unloaded in DS or in a separate flocculation decanting tank to separate solid suspensions. P is removed from the system through chemical precipitation. PHOSTRIP type systems associated with activated sludge ones can insure an effluent with a total content of P under 1,5 mg/l, before filtration.

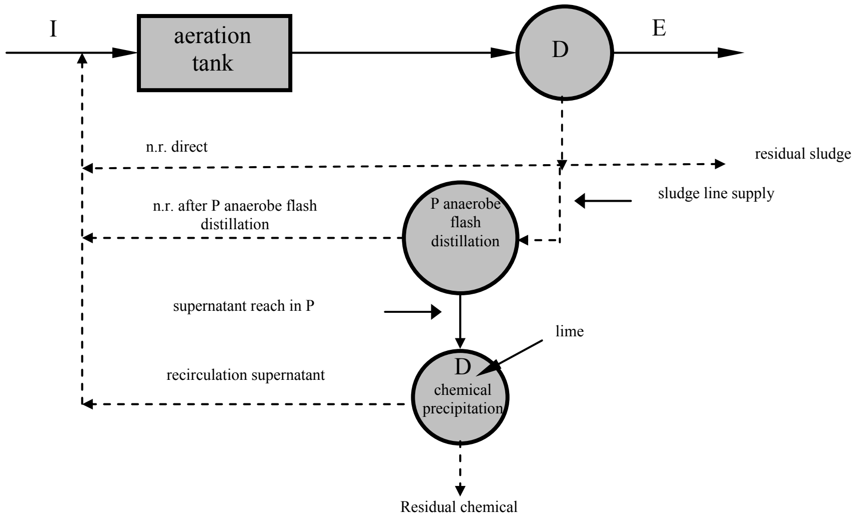


Fig. 2. Technologic diagram for Phostrip procedure:
I – influent; D – decanter; E – effluent

**Procedure with sequential functioning tanks**

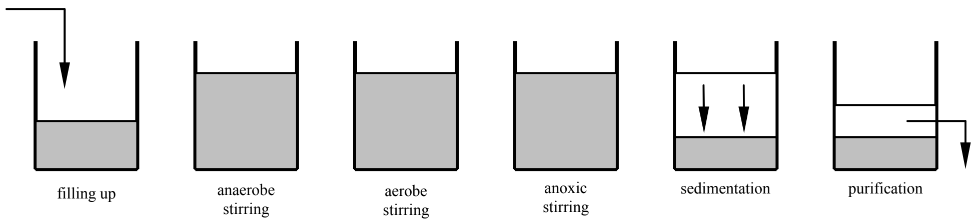


Fig. 3. System with sequential loading tanks

The system (fig. 3) can operate so that it insures any combination of C oxidation with N reduction and P removal. A simple representation of this system is shown in the figure above.

## CONCLUSIONS

### Advantages and disadvantages of biologic alternatives for removing phosphorous

Below is shown a general comparison of alternative procedures for removing P using biologic means [4]. Biologic methods provide more advantages regarding the integration in the nutrients removal process in the treatment stations. Because a great part of the procedures success depends on specific local conditions, it is recommended that pilot stations tests should be performed.

<u>**A/O procedure** (retaining P on water surface)</u>

**Advantages:** Relatively simple functioning compared to other procedures. Residual sludge has a relatively high concentration of P 3-5% and a fertilizing value. Hydraulic retention time relatively short. In cases when only a part of P should be reduced, it can be supplemented with nitrification.

**Disadvantages:** It does not have the capacity to ensure separately the removal of some big quantities of N and P. Questionable performances of operation at low temperatures. It needs high values of $CBO_5$: P ratio. Together with minimizing the retention time of cells in the aerobe medium, a higher value of oxygen transfer might be needed. Limited flexibility in operation.

**Phostrip procedure** (removing P on sludge line)

**Advantages:** It can be incorporated in the treatment stations with existent n.a. Flexible process. P removal process is not restricted by $CBO_5$: P. ratio. There are many installations like this in the USA. Significant lower consumption of chemical reactives than needed for chemical precipitation in biologic phase. It can lead to orthophosphates concentrations of effluent, under 1,5mg/l.

**Disadvantages:** It needs lime addition for P precipitation. It needs a high concentration of $O_d$ mixture to prevent P release in the final decanter. Cleaning the lime deposits can be considered a maintenance problem.

**Procedure with sequential functioning tanks**

**Advantages:** The process is very flexible for combining N with P removal. The process is simple. The suspensions from the mixture should not be washed in the opposite direction of hydraulic flow.

**Disadvantages:** Convenient only for small flows. Extra units are needed. The effluent quality depends on the decantation easiness. The design data available are limited.

Reducing these constituents can be achieved with or without chemical addition when changing the tank's functionality. P can be removed by chemical addition with coagulation reactives or biologically, without coagulation reactives addition [3]. In the configuration shown above, releasing P and reducing $CBO_5$ can take place during anaerobe mixing phase and reducing P in the next phase of aerobe mixing. Modifying the reaction time, nitrification or N removal can be obtained. A complete cycle total time can vary from 3 to 24 hours. In anoxic phase, a source of C as support for de-nitrification is needed, represented either by an external source, or by endogen respiration of existing biomass.

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