

DISSOLVED ORGANICS REMOVAL BY SOLID–LIQUID PHASE SEPARATION (ADSORPTION AND COAGULATION)

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ABSTRACT

To improve the organics removal efficiency of surface water treatment technologies, powdered activated carbon (PAC) has often been added. Some of the PAC particles with the dissolved organics already adsorbed are present in the form of a colloidal quasi-colloidal dispersion and can be removed most efficiently by coagulating and flocculating them together with the natural suspended solids. This, however, cannot be accomplished unless the PAC is added 3–5 minutes ahead under violent stirring of the water to be treated. Laboratory data demonstrated that the PAC and the Al-hydroxides formed of the coagulant (Al-salt) added remove different types of organics from the water and consequently do not compete with each other.

KEYWORDS

Powdered activated carbon (PAC), coagulation, flocculation, dissolved organics removal, adsorption, solid-liquid phase separation.

INTRODUCTION

The organic substances present in surface waters can be classified basically into two categories, one comprising the metabolic products of the biological processes of the living world (except man) in the catchment, such as vegetal matter, humic and lignine substances, animal excrements, etc., the other mostly the pollutants discharged into the waters as a corollary to human activities. These latter include also substances which are in small quantities already (in concentrations of a few $\mu\text{g/L}$) dangerous to higher-order living organisms and thus also to man himself. These are referred to as organic micro-pollutants.

The organic compounds forming the major part of the organic content in surface waters are, however, vegetal matter of no health concern and have been the natural components of these waters for millenia. Beyond certain concentration levels they affect the colour of water, making it repellent and unfit for drinking, stabilizing colloids and acting as complexors. This is why the removal of natural organics has been regarded as a basic operation in the treatment of surface waters originating from some (forested, marshy) catchments.

At the intakes of waterworks the organics may be present in dissolved or suspended forms, or are attached to the suspended solids. Some originally dissolved organics (thus some micropollutants) may be bonded firmly to the suspended solids and may therefore be regarded as part of the latter.

The removal of organics of human origin and of those causing colour and occasionally taste and odour complaints belongs to the traditional operations in the treatment of surface waters. Over the past 10-15 years reduction of the level of organics considered "harmless" formerly has also been recognized as an important function in waterworks practice. These are the organics which tend to react with the disinfecting chlorine to form trihalomethane compounds. The hazard of carcinogenic THM compounds could be lowered substantially by reducing the concentration of the THM precursor organics. The removal of the natural organics considered harmless for long, but recognized as THM precursors, has consequently entered the standard technology of surface water treatment.

Organics are removed most effectively from surface waters by adsorption on activated carbon. In waterworks practice activated carbon is used in granulated or powdered forms. GAC is substantially simpler but more expensive to use than PAC. Columns filled with GAC are operated without any major difficulty, whereas the use of PAC calls for the solution of a number of technological problems.

THEORETICAL CONSIDERATIONS

Part of the activated carbon powder forms a colloidal, quasi-colloidal dispersion with water, the removal of which - together with the organics adsorbed - with the desirable efficiency can only be solved by an effective solid-liquid phase separation method. Because of the colloidal, quasi-colloidal properties of the dispersion, a variety of coagulation-flocculation, sedimentation (or flotation) and filtration (sand filtration) processes must be introduced.

The conventional solid-liquid phase separation technologies including coagulation-flocculation, sedimentation (flotation) and filtration proved successful in lowering materially the organic content. Depending on the properties of the raw surface water and on the level of the treatment technology applied, organic removal rates ranging from 20 to 60 per cent have been achieved by conventional solid-liquid phase separation methods at the waterworks drawing on surface water in Hungary.

It should be evident that in the course of conventional solid-liquid phase separation the suspended organics are removed together with the mineral (inorganic) particles. The amount of these organics is, however, appreciably smaller than the total removed, the latter including dissolved organics as well. In the physical sense, removal is accomplished in the sedimentation (flotation) and filtration processes, but the dissolved organics are made accessible to solid-liquid phase separation treatment by coagulation.

Coagulation processes are thus of paramount importance in the removal of dissolved organics. The same applies to the particles of the colloidal, quasi-colloidal dispersion as well, regardless of whether these are of mineral origin, or were introduced as the activated carbon powder.

Removal of the PAC - and thus also of the organics - will be most effective if the PAC as adsorbent is added to the water ahead of the aluminium- or iron(III) salt coagulant. This way of application appears logical, but implies that the PAC removed (adsorbs) potentially also some of the organics, with which the metal hydroxides formed of the coagulant can enter into permanent bonds and which would anyhow be removed by the conventional solid-liquid phase separation operation. In such cases the efficiency of the PAC is impaired, since the expensive adsorbent (the PAC) is used for removing from the water the organics which would be extracted by the cheap coagulant equally well. The PAC and the coagulants compete thus with each other in removing certain types of organics.

EXPERIMENTS

The extent to which the PAC and the aluminium sulphate coagulant perform parallel functions in organics removal was studied in the laboratory on a particular surface water (the River Danube). The experiments were performed to ascertain separately the amounts of organics (expressed in terms of the COD) removed when the coagulant and the PAC were added alone to the water. In subsequent experiments the amount of organics extracted by the combined application of the PAC and coagulant was also evaluated. The experimental data are shown in Table 1. The total of the organics removed separately by the PAC and the coagulant was found to largely equal the amount of organics removed by the simultaneous addition of the two.

Table 1 Organic removal by aluminium sulphate and PAC separately and in combination

	1.	2.	3.	4.
Raw water	COD removed with aluminium hydroxide flocs	COD removed with PAC	Total of columns 1 and 2	COD removed by combined treatment with aluminium hydroxide and PAC
COD (mg/L)	COD (mg/L)	COD (mg/L)	COD (mg/L)	COD (mg/L)
5.0	1.8	2.3	4.1	4.1
3.5	1.4	2.5	3.9	3.0
12.0	3.0	3.2	6.2	6.4
11.2	3.6	3.0	6.6	6.6

The experiments were repeated on samples in which the amount of organics was increased by the addition of paper-mill sulphite liquor. As will be perceived from Table 1, the results obtained resembled those found in the preceding run.

RESULTS AND DISCUSSION

It was concluded therefore that as regards the removal of organics present in Danube water the PAC and the coagulant do not compete with each other, the organics adsorbed by the PAC belonging to another type than those bonded by the aluminium hydroxide by adsorption and hydrogen bonds. It was concluded further that the foregoing statement applies not only to Danube water, since different types of organics responded to the adsorption and coagulation processes also in the samples of organic concentrations elevated artificially by a special blend of organic substances.

The effective way of using PAC consists thus of adding it to the raw water preferably three-to-five minutes, if conditions otherwise permit, before the coagulant. This length of contact time is needed for the PAC to adsorb some of the dissolved organics and to become part of the suspended solid content of the surface water. The coagulation-flocculation process makes the PAC accessible to removal from the water by simple solid-liquid phase separation operations. Moreover, the dissolved organics not adsorbed on the PAC become also suited to solid phase separation in the coagulation-flocculation process. The adsorption and particulate properties of the PAC transform into a state accessible to solid-liquid phase separation, also the dissolved organics, which the metal hydroxides formed if the coagulant fails to bond.

CONCLUSIONS

1. The PAC particles used as adsorbents - and the organics adsorbed on them - can be removed most efficiently by adding the coagulant (e.g. Al-salt) after the PAC to the water. In this case the PAC particles can be removed in a manner similar to the removal of the natural suspended solids by conventional solid-liquid phase separation techniques (coagulation, flocculation, sedimentation or flotation, sand filtration).
2. In the treatment of Danube water, the PAC and the Al-hydroxides formed from the coagulant removed different types of dissolved organic substances.
3. In the removal of dissolved organics the nascent Al-hydroxide sol particles and the PAC particles do not compete with each other.
4. The optimal point of introducing the expensive PAC should be selected preferably so as to precede by 3-5 minutes the addition of the coagulant. The PAC will adsorb but negligible quantities of the organics which can be removed by the Al-hydroxides as well.