ACTIVATED CARBON APPLICATIONS

For Drinking Water Production

Water is an essential element of life: it accounts for 70% to 80% of the weight of a human being. The quality of water is an important parameter that affects all aspects of the well-being of ecosystems and mankind, from human health, to food production, economic activities and biodiversity.

Today, more than ever, water resources are under pressure: demographic growth, intensive agriculture, industrial activities, and climate change, are weakening the prime natural resource of our planet. No source of this vital resource is spared: groundwater, rivers and oceans are all threatened by pollution and are universally of concern of international authorities. The nature of the pollutants are diverse. They can be naturally occurring (taste and odors, algae toxins, organic matter) or related to human activities (hydrocarbons, heavy metals, pharmaceuticals, pesticides, surfactants, endocrine disruptor). The contaminations can be both seasonal or persistent.

While aquatic pollutants are known and classified, their effects – especially in combination - are still questionable, especially when it comes to industrial chemicals. To prevent the population to be exposed to these contaminants in drinking water, operators are required to remove them, and to comply with more and more stringent regulations.

One of the easiest ways to do this, especially in case of temporary pollution, is to use Powdered Activated Carbon (PAC). Activated carbon is a very reliable adsorbent with a wide spectrum of effectiveness on numerous pollutants. However, there are many types of powdered activated carbons. Although, activated carbons appear merely as an innocuous black solid, each one has a specific characteristics with an affinity to certain pollutants.

This paper will describe the diversity and specificity of Jacobi's activated carbons intended for drinking water treatment, and provide guidance on their relative performances against the following pollutants:

- Organic matter
- Pesticides
- Taste and Odors
- Emerging pollutants

This paper is also to be used as a guide for:

- Selecting the activated carbon which will be appropriate for treating the target pollutant(s);
- Determining the efficiency of the activated carbon already installed in a plant in relation to existing regulations and emerging pollutants.

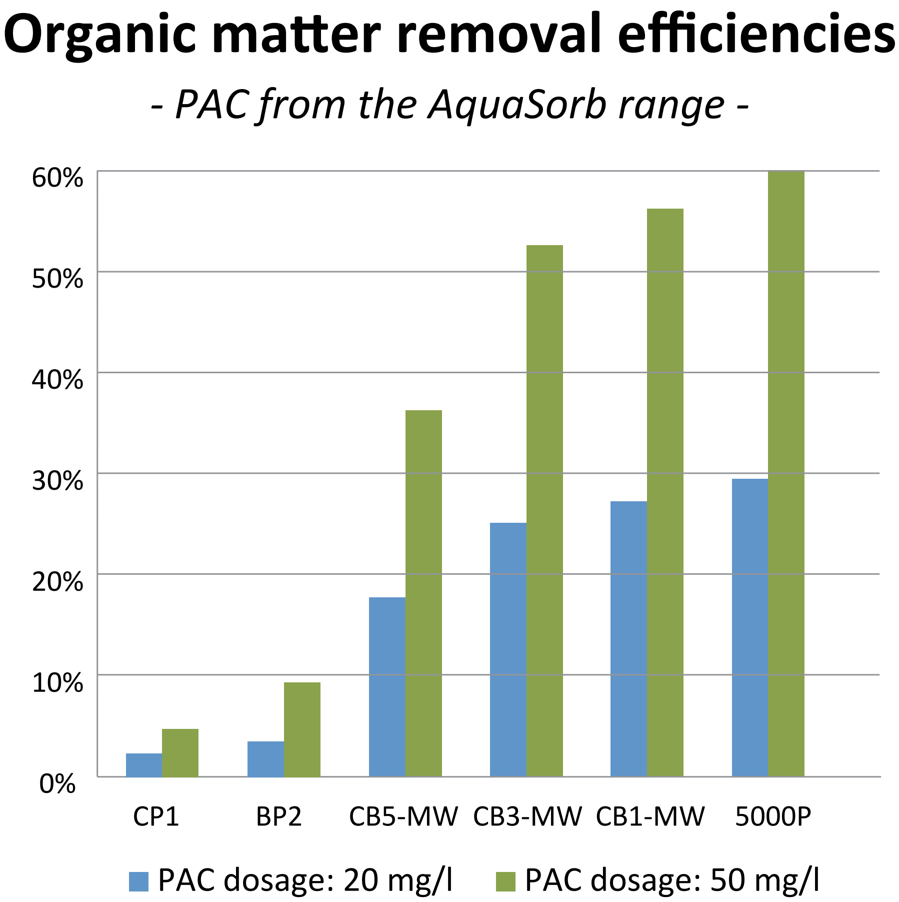
Our aim is to contribute to water quality control whilst optimizing treatment plant operating costs.

Organic matter (OM) removal

Many natural organic substances are present in groundwater or surface water, such as humic substances, hydrophilic and carboxylic acids. Most are related to the decomposition of plants and animals living in the catchment area or in the river itself. Organic matter can also be related to urban activities. This great diversity is also reflected in the chemical and physical properties of the pollutant.

Each step of the drinking water treatment process contributes in the elimination of part of the organic matter, especially the coagulation/flocculation/settling phase. However, the removal efficiency may be insufficient to reach the target required by regulations (2 mg/L maximum of TOC in most countries), in particular when the concentration of OM in raw water is high.

In this case, adsorption is a particularly efficient treatment to reduce the organic matter concentration, as illustrated by the test results below:



Trials on Cher river raw water done by PICA Jacobi Lab in Vierzon (France) in 2011
Kinetic test at 10 minutes of contact time
Measurement of the optical density at 254 nm (initial OD = 0,08)

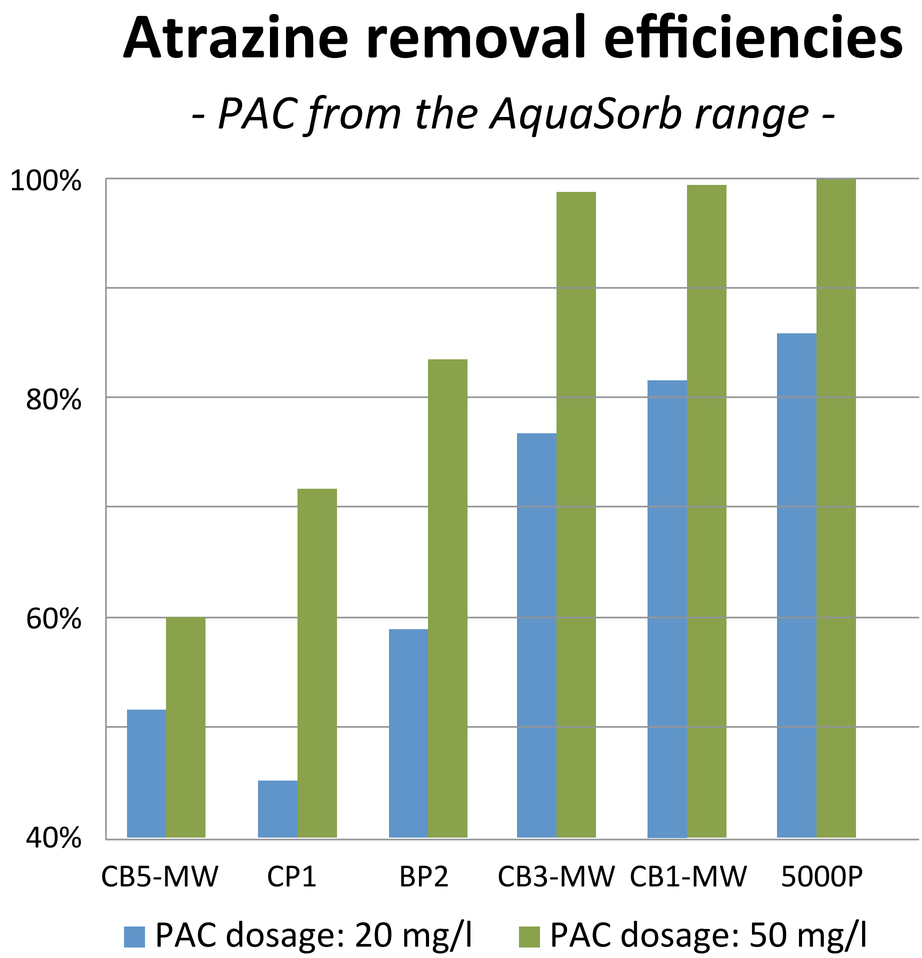
As can be seen, the choice of the PAC type to use will depend on the expected removal efficiency and economic factors in implementing the use of the grade selected.

Pesticides removal

Pesticides are a perpetual problem in water treatment. They are often present in raw water sources, varying in their nature and concentration over different periods of time. Worldwide water treatment plants must comply with increasingly strict regulatory limits for pesticide levels in the treated water supplied to the network.

Generally, activated carbon is the only technology available in the drinking water treatment process that is able to efficiently remove pesticides.

The graph below illustrates the removal efficiency of different activated carbons on atrazine, a pesticide widely recognized as an indicator of adsorption characteristics for this type of pollutant.

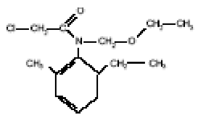
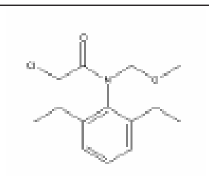
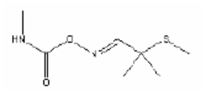
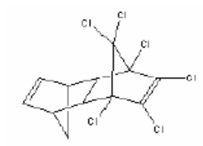
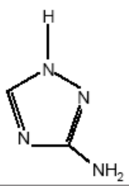
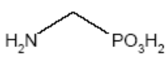
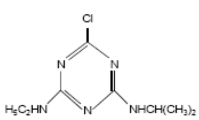


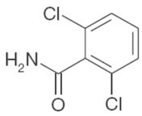
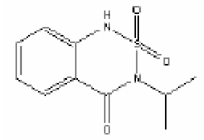
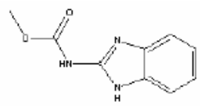
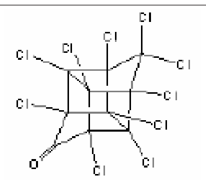
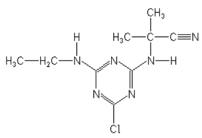
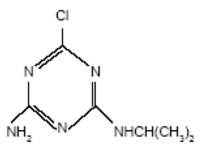
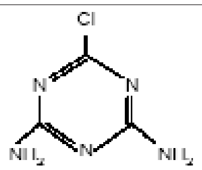
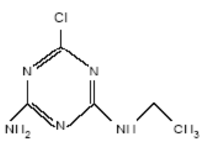
Trials on Cher river raw water done by PICA Jacobi Lab in Vierzon (France) in 2011
Kinetic test at 10 minutes of contact time
In the presence of organic matter

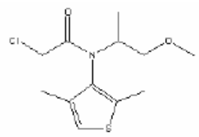
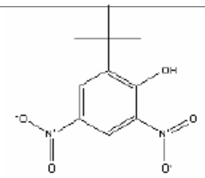
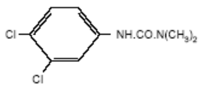
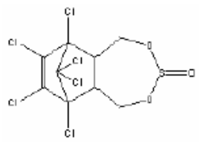
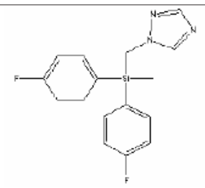
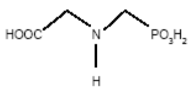
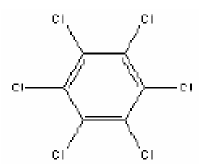
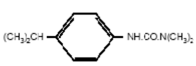
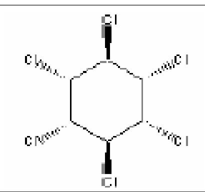
The nature of pesticides is incredibly diverse, and they vary greatly according to their use, composition and physicochemical properties. However, all types generally have an affinity for adsorption by activated carbon.

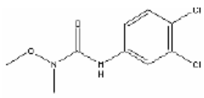
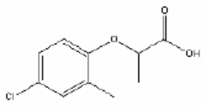
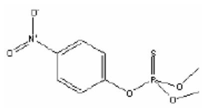
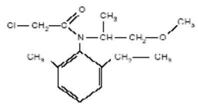
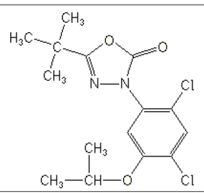
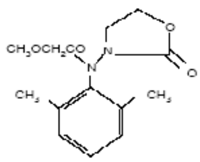
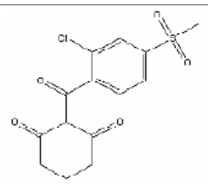
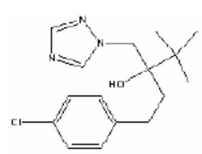
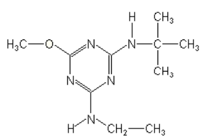
The table below provides guidance to the relative level of affinity between selected pesticides and activated carbon.

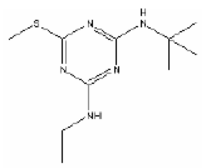
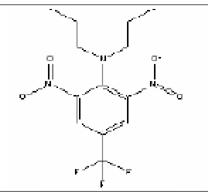
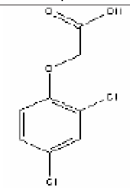
Compounds are classified with respect to the reference pesticide, atrazine, for which activated carbon affinity is indicated by two drops "💧".
The higher the number of "💧" (drops), the higher the affinity level.

Compound	Developed formula	Family	Use	Molecular weight (g/mol)	Solubility (mg/l)	Log Kow*	Aptitude of the molecule to be adsorbed
Acetochlorine		Chloroacetamides	Herbicide	270	233	2,5	💧💧💧
Alachlorine		Chloroacetamides	Herbicide	270	242	3,1	💧💧
Aldicarb		Carbamates	Insecticide	190	4,900	1,2	💧
Aldrin		Organochlorinated products	Insecticide	365	0	6,5	💧💧💧
Aminotriazole		Triazoles	Herbicide	84	280 000	-0,9	💧
AMPA		Amino-phosphonates		111	/	/	💧
Atrazine		Triazines	Herbicide	216	33	2,3	💧💧

Compound	Developed formula	Family	Use	Molecular weight (g/mol)	Solubility (mg/l)	Log Kow*	Aptitude of the molecule to be adsorbed
BAM (2,6-dichlorobenzamide)		Benzamides		226	694	/	💧💧
Bentazone		Benzothiadiazones	Herbicide	240	570	-0,5	💧
Carbendazime		Benzimidazoles	Fungicide	191	8	1,5	💧💧💧
Chlordecone		Organochlorinated products	Insecticide	491	8	4,5	💧💧💧
Cyanazine		Triazines	Herbicide	241	171	2,1	💧
DEA(Desethyla-trazine)		Triazines		188	375	1,5	💧💧
DEDIA (Desethyl-deisopropyla-trazine)		Triazines		146	/	/	💧💧
Desethylterbuty-lazine		Triazines		/	/	/	💧💧
DIA (Deisopropy-latrazine)		Triazines	Herbicide	174	208	1,2	💧💧

Compound	Developed formula	Family	Use	Molecular weight (g/mol)	Solubility (mg/l)	Log Kow*	Aptitude of the molecule to be adsorbed
Dimethenamide		Chloroacetamides	Herbicide	276	1,174	1,9	💧
Dinoterbe		Dinitrophenols	Herbicide	240	5	1,9	💧💧💧
Diuron		Substituted urea	Herbicide	233	42	2,9	💧💧💧
Endosulfan (α)		Organochlorinated products	Insecticide	407	0	4,7	💧💧💧
Flusilazole		Triazoles	Fungicide	315	45	3,7	💧💧💧
Glyphosate		Amino-phosphonates	Herbicide	169	12,000	-4,1	💧
HCB (Hexachloro-benzene)		Organochlorinated products	Fungicide	285	0	5,7	💧💧💧
Isoproturon		Substituted urea	Herbicide	206	55	2,5	💧💧
Lindane products		Organochlorinated	Insecticide	291	7	3,7	💧💧💧

Compound	Developed formula	Family	Use	Molecular weight (g/mol)	Solubility (mg/l)	Log Kow*	Aptitude of the molecule to be adsorbed
Linuron		Substituted urea	Herbicide	249	81	3,0	💧💧💧
Mecoprop		Aryloxy-acids	Herbicide	215	734	1,3	💧
Methyl-parathion phosphorated		Organo- compounds	Insecticide	263	55	3,0	💧💧💧
Metolachlore		Chloroacetamides	Herbicide	284	488	2,9	💧💧💧
Oxadiazon		Oxidiazoles	Herbicide	345	1	4,9	💧💧
Oxadixyl		Phenylamides	Fungicide	278	3,400	4,5	💧
Sulcotrione		Triketones	Herbicide	329	165	<0	💧
Tebuconazole		Triazoles	Fungicide	308	36	3,7	💧💧💧
Terbumeton		Triazines	Herbicide	225	130	3,0	💧

Compound	Developed formula	Family	Use	Molecular weight (g/mol)	Solubility (mg/l)	Log Kow*	Aptitude of the molecule to be adsorbed
Terbutryne		Triazines	Herbicide	241	22	3,7	💧💧💧
Trifluraline		Toluidines	Herbicide	335	0	5,1	💧💧💧
2,4 D		Arylo-acids	Herbicide	221	45,000	2,6	💧💧

(*) octanol/water distribution coefficient

Note : The results described above are based on laboratory studies conducted by Jacobi Carbons and various independent laboratories. Efficiencies indicated in the tables are provided in a qualitative format.

It is important to recognise that adsorption capacities depend on numerous factors, including:

- Resource quality
- Type of treatment process
- Type of compound to be eliminated
- Concentration of compound to be eliminated
- Level of reduction required
- Presence of other compounds (which may compete with the adsorption of target compounds)

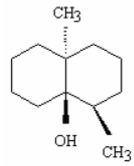
As each case is unique, please do not hesitate to contact your Jacobi Carbons sales representative. Jacobi Carbons has considerable technical resource capability to assist in the selection of the most suitable activated carbon to achieve the treatment objectives required. Our AquaSorb™ range is extensive and includes products from a variety of raw materials and activation methods. In addition, our manufacturing plants are able to produce materials with specific properties to optimize the treatment outcomes.

Taste & odor removal

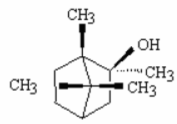
In recent years, the intensity and frequency of taste and odor problems in drinking water have increased throughout the world. Beyond the aesthetic problem for the consumer, this also invariably creates uncertainties about the quality and safety of water.

The compounds responsible for taste and odor problems can have an anthropogenic (industrial or municipal discharges) or biological origin. In the latter case, they are produced by microscopic organisms such as cyanobacteria.

The two most common compounds are geosmin and 2-methylisoborneol (MIB). Geosmine, which has an earthy smell, is often produced by planktonic cyanobacteria (suspended in water). MIB, which has a musty smell, is most often produced in biofilm developing on rocks, aquatic plants and sediment. These compounds are detected by human olfactory cells at very low concentrations, even in the range of a few ng/l.



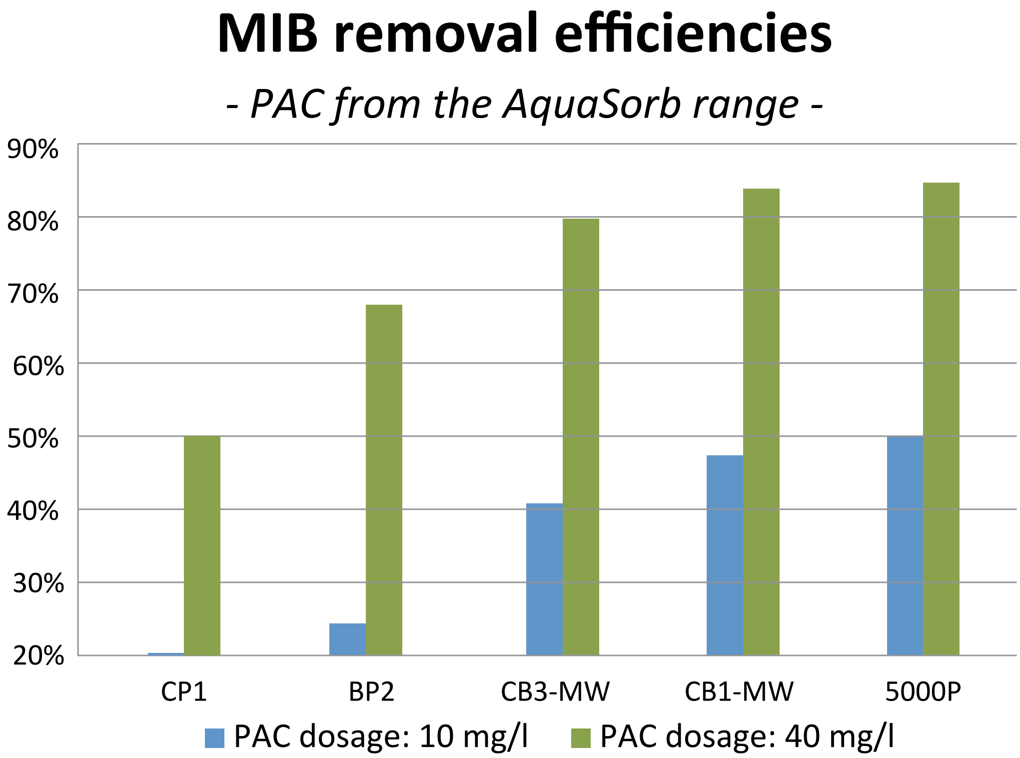
géosmine



2-méthylisobornéol

It has not yet been determined if any such risk is posed by geosmin and MIB on human health and the environment. Furthermore, it is difficult to predict the occurrence of such phenomena as triggering factors are poorly known.

Conventional treatments such as oxidation do not necessarily achieve the destruction of these compounds to levels below this very low detection limit, hence the implementation of the use of activated carbon. The results presented below are based on scientific data established and published by independent laboratories, operated by the Australian Water Quality Center.

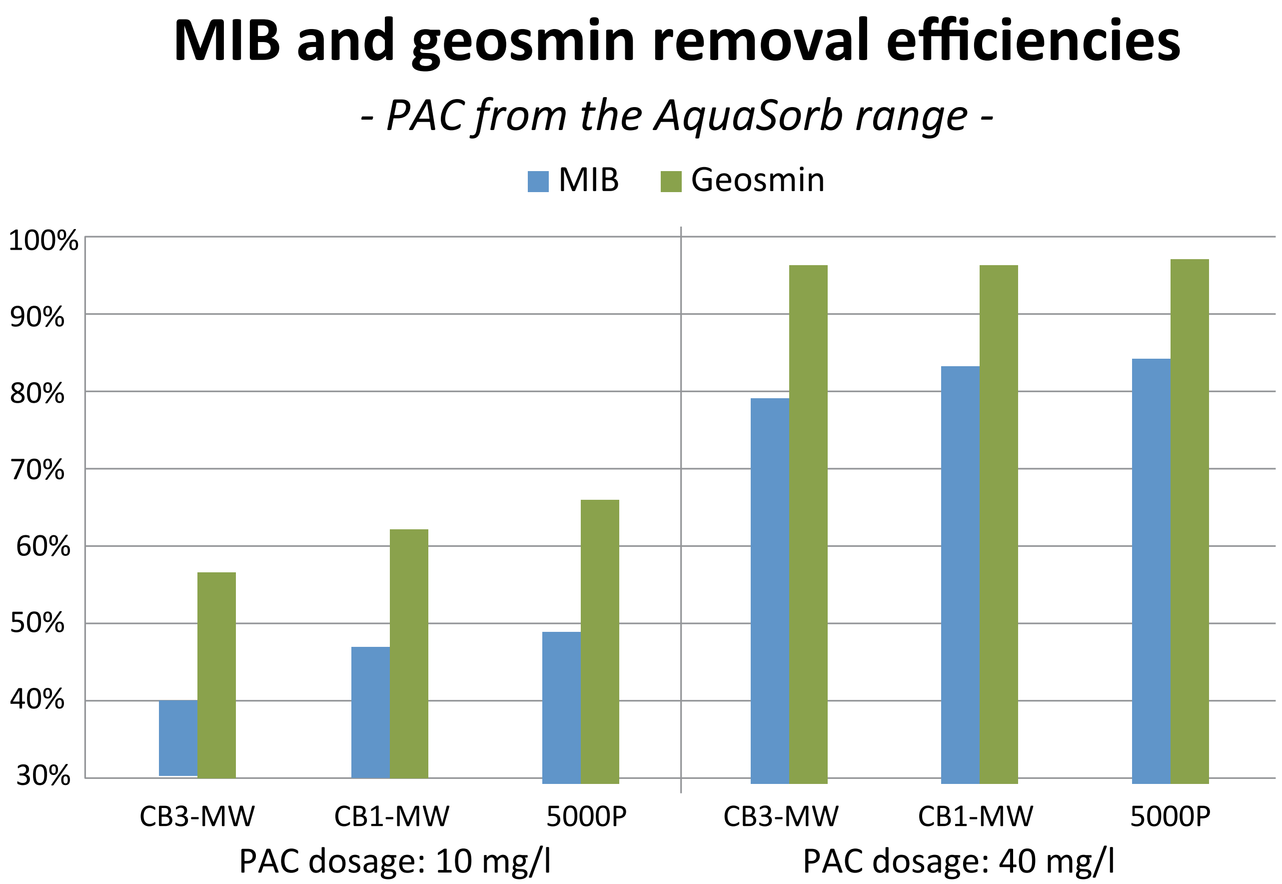


Compiling of several test results done on tap water spiked at a target concentration of 100ng/L of MIB
Kinetic test at 20 minutes of contact time
In presence of organic matter

The most efficient reduction of MIB requires a predominately mesoporous activated carbon. This observation is consistent with the size of the molecule to be removed.

However, the choice of the PAC type to use depends of the expected removal efficiency and economy prevailing in the treatment process.

As shown below, the adsorption of geosmin is slightly improved over that of MIB.



Trials done by AWQC on tap water spiked at target concentrations of 100ng/L of MIB and geosmin
Kinetic at 20 minutes of contact time
In the presence of organic matter

A similar test has shown that doubling the contact time does not have much influence. The removal of MIB is slightly increased, but for geosmin, removal efficiency remains the same. We can therefore deduce that a contact time of approximately 20 minutes is sufficient to reduce these compounds to acceptable levels.

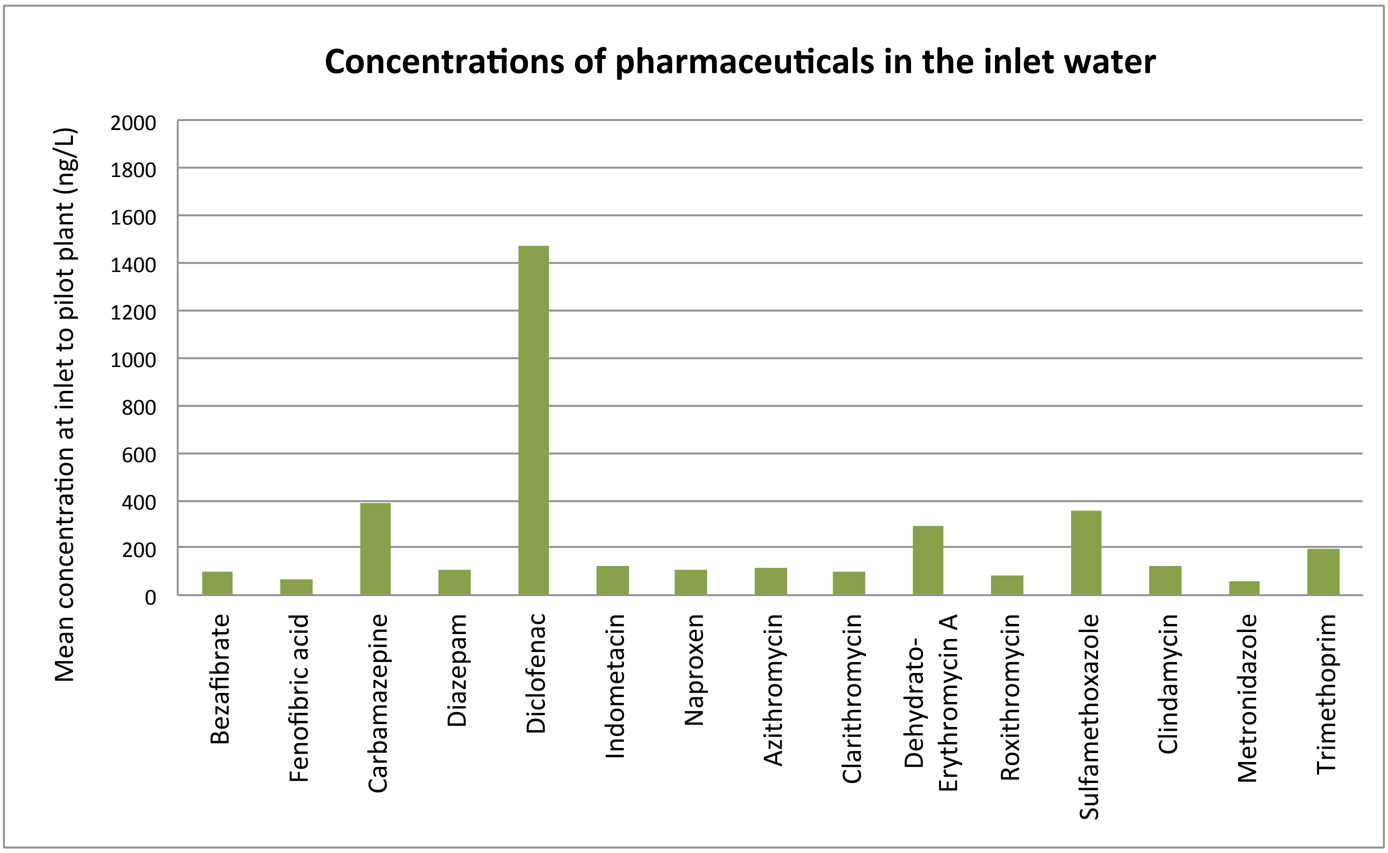
Emerging pollutants

The presence of active pharmaceutical ingredients, radio-opaque substances and endocrine disrupting chemicals in raw water sources is a relatively new emerging issue in relation to drinking water quality.

- *German study*

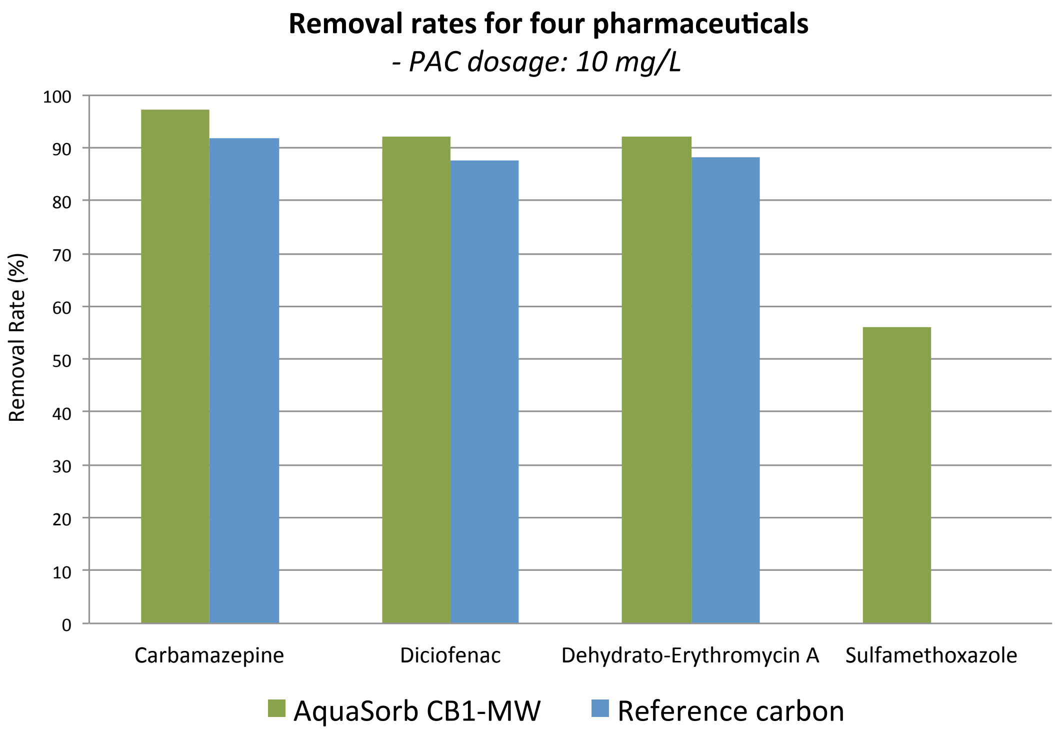
A study for the removal of micro pollutants has been carried out by the Biberach University of Applied Science. Powdered activated carbon has been used to remove pharmaceuticals and radio-opaque substances from water in a plant in southern Germany. AquaSorb™ CB1-MW has been tested and was proven to be suitable for the removal of these substances, as shown in the graph below.

The graph shows the concentrations of pharmaceuticals which were found to be present in an amount higher than the detection limit for at least one of the samples.

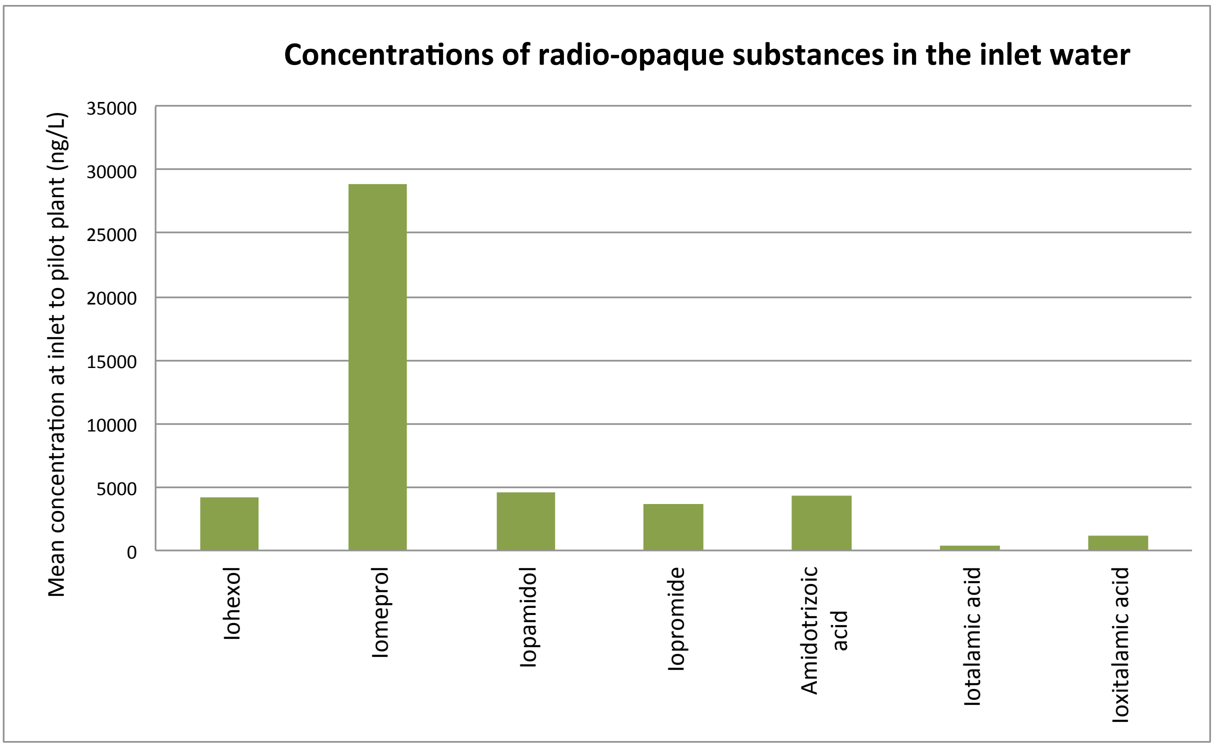


The removal rate for all substances listed is higher than 50% and in some cases as high as 97%.

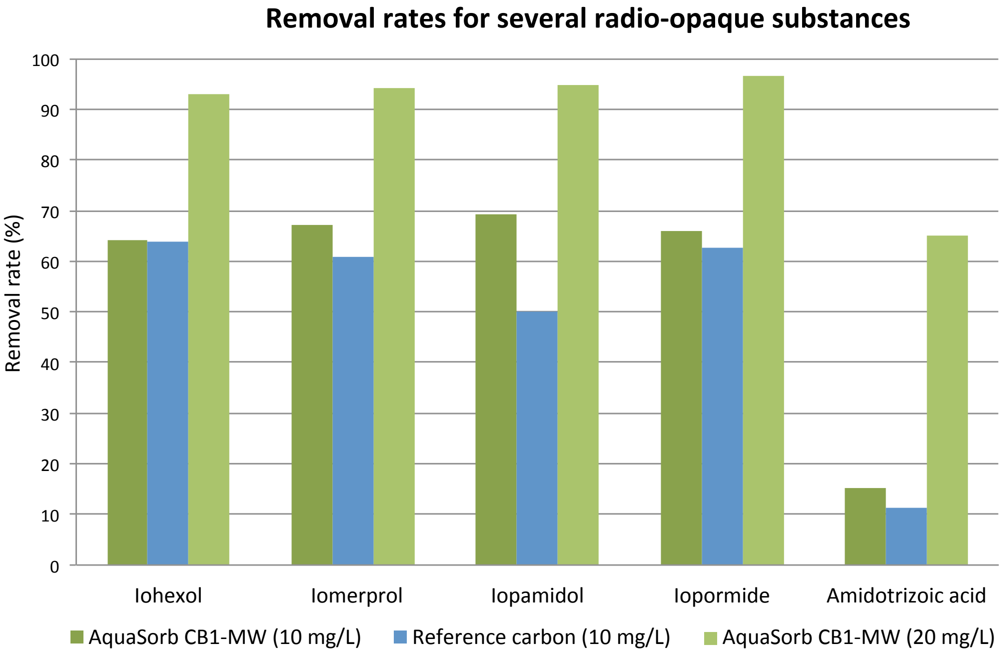
For the substances which were present at the highest concentrations a comparison to the reference carbon was made. The results are shown in the figure below:



As for radio-opaque substances, the investigation has been limited to iodine containing substances because they are the most present and most persistent members of this substance group in water. The figure below shows the inlet concentrations in the pilot plant.

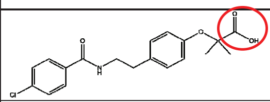
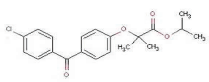
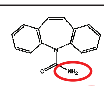
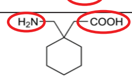
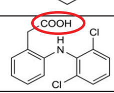
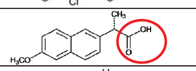
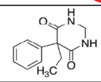
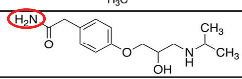
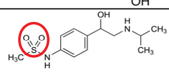


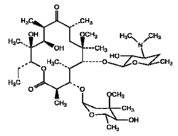
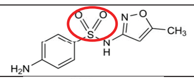
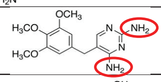
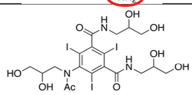
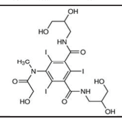
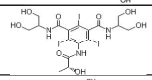
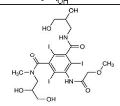
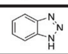
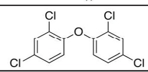
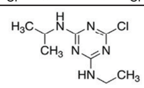
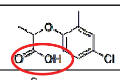
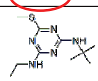
Radio-opaque substances are highly polar molecules in comparison to the pharmaceuticals investigated within this study. Therefore they show significantly lower removal rates. Ionic substances additionally showed lower removal rates than the non-ionic substances which were included. For all substances the removal rate can be enhanced by higher carbon dosage rates. The differences of the removal rates and a comparison to the reference carbons performance are shown in the figure below.



- *Swiss study*

Other trials have been performed by Ecole Polytechnique of Lausanne (Switzerland) on the following 21 micro-pollutants :

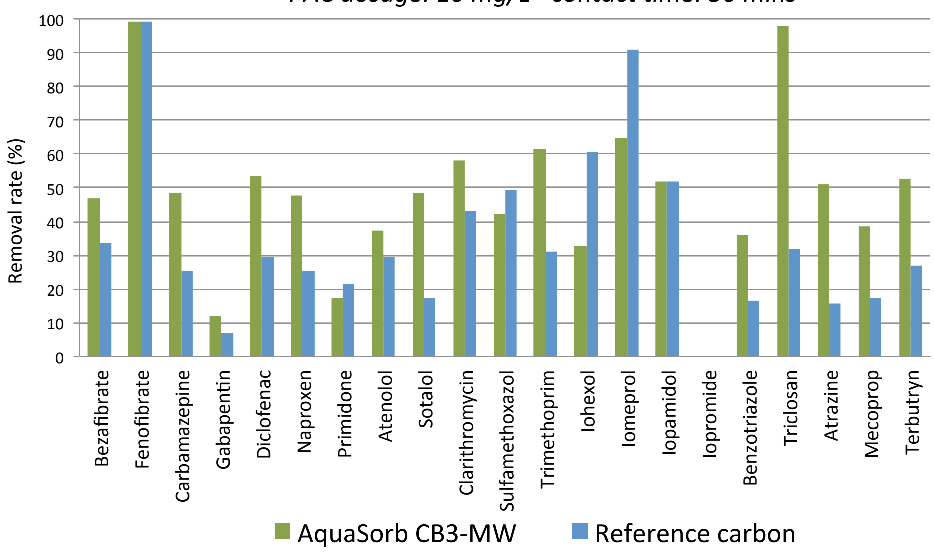
Family/Fonction		Substances	numéro CAS	ng/L en moyenne	Structure de la molécule	poids moléculaire	log Kow
Pharmaceuticals	Lipid regulators	Bezafibrate	41859-67-0	600		361.82	4.25
		Fenofibrate	49562-28-9	60		360.83	5.19
	Antiepileptic drugs	Carbamazepin	298-46-4	200		236.27	2.45
		Gabapentin	60142-96-3	2200		171.24	-1.1
	Analgesics	Diclofenac	15307-86-5	1300		296.15	4.51
		Naproxen	22204-53-1	250		230.26	3.18
		Primidone	125-33-7	80		218.25	0.91
	Beta Blockers	Atenolol	29122-68-7	450		266.34	0.16
		Sotalol	3930-20-9	160		272.36	0.24

Pharmaceuticals	Antibiotics	Clarithromycin	81103-11-9	600		747.95	3.16
		Sulfamethoxazole	723-46-6	110		253.28	0.89
		Trimethoprim	738-70-5	100		290.32	0.91
	X-Ray contrast media	Iohexol	66108-95-0	6800		821.14	-3.05
		Iomeprol	78649-41-9	6300		777.09	-2.79
		Iopamidol	60166-93-0	720		777.08	-2.42
		Iopromide	73334-07-3	2000		791.11	-2.05
Biocides/ Pesticides	Corrosion inhibitors	Benzotriazole	95-14-7	**3400**		119.12	1.44
	Biocide	Triclosan	3380-34-5	**1800**		289.54	**4.76**
	Herbicides	Atrazin	1912-24-9	10		215.68	**2.61**
		Mecoprop	93-65-2	70		214.65	**3.13**
	Algicides	Terbutryn	886-50-0	10		241.36	**3.74**

The removal efficiencies are shown graphically below:

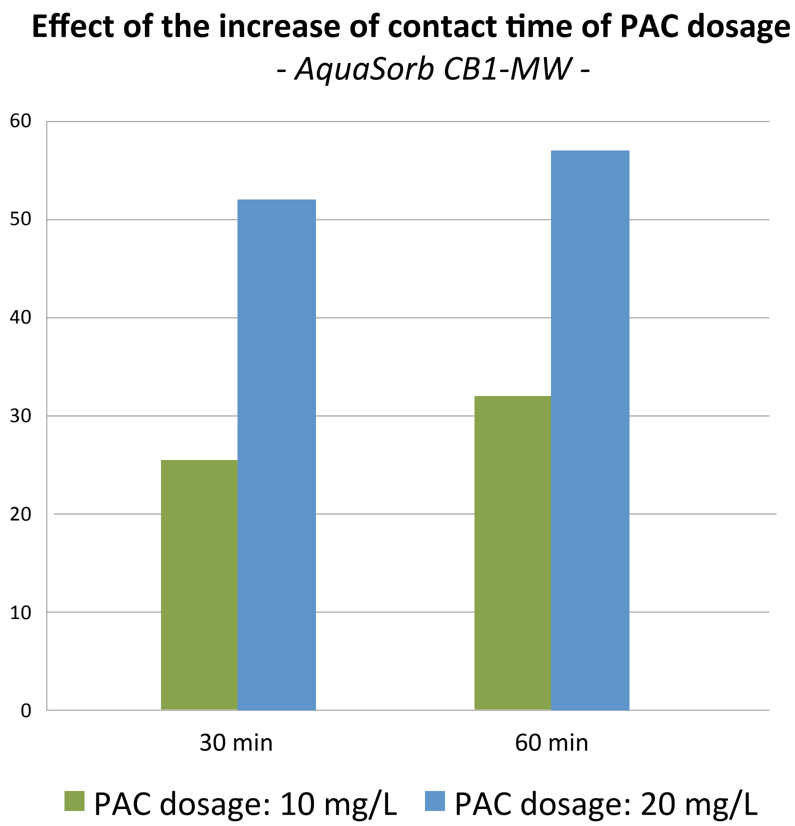
Removal rates for different pharmaceuticals and radio-opaque substances

- PAC dosage: 10 mg/L - contact time: 30 mins



AquaSorb™ CB3-MW proved to be the most efficient activated carbon to remove these compounds.

The study also shows that the increase of the PAC dosage has a better effect on the removal efficiency than the increase of contact time, as illustrated in the graph below:



As each case is unique, please do not hesitate to contact your Jacobi Carbons sales representative. Jacobi Carbons has considerable technical resource capability to assist in the selection of the most suitable activated carbon to achieve the treatment objectives required. Our AquaSorb™ range is extensive and includes products from a variety of raw materials and activation methods. In addition, our manufacturing plants are able to produce materials with specific properties to optimize the treatment outcomes.

For more information or to contact Jacobi visit: www.jacobi.net

JACOBI-TIS-AQUASORB-RAW-WATER-A4-ENG-A0412

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