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Short Report on the absorption capacity of AdAbSorb (adsorbent absorber) of oil on water

DR. LOESER & ULBRICH UMWELTTECHNIK UG - R & D DEPARTMENT

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Content

1 OCCASION

AdAbSorb is a adsorbent absorbers for various hydrocarbons (HC). Dr. Loeser works as a recognized expert in the field of contaminated sites and remediation of contaminated sites and often has to do under this work area with the remediation of groundwater contamination by HC-loads in and on the ground.

In the water purification and water treatment adsorption plays a special role for pollutant removal. Adsorption processes are often a very effective solution for low to medium pollution.

There were mainly identified five common application areas. These are in the following:

1. Restoration of oil damage and groundwater
2. Remediation of oil spills on water
3. Purification of waters of dissolved HC (BTEX contamination)
4. Cleaning of rainwater from traffic and road areas
5. Treatment of polluted rainwater for domestic water extraction

2 TOPIC AND TARGET

From the preliminary investigations carried out to adsorb dissolved organic matter and oil-elimination can be concluded, that there are practical applications with a high market potential in the field of environmental technology and in particular in water treatment for the novel absorber AdAbSorb. These include the

- Elimination of polycyclic aromatic hydrocarbons (PAHs) from the aqueous phase (including landfill leachate treatment), Elimination of highly volatile halogenated hydrocarbons from highly contaminated wastewater, elimination of BTEX compounds (e.g. deposit water treatment, groundwater remediation), elimination of organic substances contained in water in particular with non-polar properties
- Use of residual oil for AdAbSorb
- Use of AdAbSorb for oil separation from fine and coarse dispersed emulsions having average oil contents with and without surfactant additives
- Use for separating oil from emulsions with high oil content.

For experimental purposes, was the AdAbSorb in nonwovens bottled (pads), which may vary in length, width and filling. The increase in volume of the oil AdAbSorb by the absorption is limited by the individual compartments of the pads. With regard to the rehabilitation of contamination by oils in the field of groundwater and surface water experiments on the capacity of the various pads were performed. It should be determined as the degree of filling of the Pads affects the AdAbSorb on the capacity.

The aim of these tests is to determine the optimum filling level of the pads.

3 STAND OF SCIENCE AND TECHNOLOGY

In surface waters and affected groundwaters accumulate increasingly resistant, i.e. biochemically stable and chemically difficult or impossible to oxidizable substances. Some of them presents a health risk, such as the complex group of organochlorine compounds with the halo forms, polychlorobiphenyls. While the truly dissolved low molecular weight organic compounds through the traditional stages of the water treatment are only slightly reduced, the membrane technology and adsorption are very effective method. Adsorption processes are always equilibrium processes, whereby the position of the equilibrium is crucial the nature of the adsorbent and the adsorbate, the concentration gradient and on the contact time dependent.

To view the adsorption, it is expedient, the dissolved organic substances in the water in polar, i.e. readily water-soluble and non-polar, that is, little or almost not divide water-soluble compounds. In raw water for water supply outweigh the polar substances, while the non-polar

substances account for the low, health and organoleptically far more significant share. For non-polar substances in water are as adsorbents activated carbon or organic polymers, for polar

substances in water activated carbon, alumina or siliceous materials. The widest spectrum of the activated carbon by far. In filtration through granular activated carbon can physiologically harmful trace substances, the lipophilic substances are eliminated about 90%. The destruction of these pollutants is then performed by thermal utilization of the adsorbent.

4 NOVELTY DEGREE

For the adsorbent AdAbSorb arise from the highly hydrophobic and lipophilic surface properties, the large internal surface area and pore structure (predominantly macro and mesopores, activated carbon has mostly only micro pores) diverse opportunities in water treatment. Hydrophobic adsorbents adsorb nonpolar organic molecules particularly efficient. AdAbSorb is able to bind the oil in the order of several times its own weight and included.

This product is a novel adsorbent which has not been used internationally for adsorption. The product can only be produced economically, if it can be assured of a minimum amount of sales by a wide application orientation. Under this project the large-scale detection of possible applications to be made.

AdAbSorb is an absorber having a similar spectrum of action such as activated carbon, and this could in principle be replaced. The testing of the new product in a laboratory scale at the Institute of Environmental Process Engineering with used model substances (low-molecular compounds, high molecular weight organic materials, non-polar low-molecular compounds) resulting adsorption capacities which are comparable to those of activated carbon. In addition AdAbSorb but include other lipophilic substances in the situation and thus enlarges the spectrum can be eliminated substances significantly. In the experiments at the Institute of Environmental Process Engineering lipophilic test substance of AdAbSorb was particularly well adsorbed. The laboratory tests for oil elimination also showed that the absorber AdAbSorb opposite activated carbon as the filter material proved more favorable for both emulsions without and with surfactant addition.

The product AdAbSorb has a very good oil wettability, such as shots with a high-speed camera of the Institute of Environmental Process Engineering made clear. The high oil absorption capacity of the adsorbent is mainly due to the strong hydrophobicity of the material, still it can be assumed that the rapid oil absorption predominantly macro- through the high wicking due to strong capillary action of the pore structure in the mesoporous size range and is caused.

It is advantageous that the adsorbent AdAbSorb can be provided at a low price is available, according to current estimates. So its regeneration is not necessarily the basic precondition for an economic use. Rather, the adsorbent loaded in the aftermath can incinerated and its energy can therefore be used. In summary, it is judged that the adsorbent AdAbSorb to adsorb

predominantly non-polar organic compounds and for separating oil from fine and coarsely dispersed oil emulsions in the field of water treatment very suitable is.

5 INVESTIGATION RESULTS OF IUV

Because of the preliminary investigations at the Institute of Environmental Engineering (IUA) of the University of Bremen headed by Prof. Räbiger was the fundamental characteristic of AdAbSorb in an immersion test with reservoir water, naturally occurring deep water that has depending on source rock has a very high salt content and with heavy metals hydrocarbons charged (especially high with benzene or BTEX shares and oil) is detected. Reservoir water to fall in gas production and the fracking. In the analysis of reservoir water with a GC-MS system, a relatively high removal rate for the BTEX substances could be detected.

The results of the test series on 11.21.2013 carried out with the sample of the reservoir water can be summarized as follows:

	Concentration before adsorption / mg l-1	**Concentration after adsorption / mg l-1**	**Adsorption / %**
benzene	790.96	158.49	79,96
toluene	301.88	49,55	83.59
Xylene (total)	222.38	32,98	85.17

Furthermore, it was to estimate and determine the degree of purification of chemical oxygen demand in comparison with contaminated water in the original, after cleaning of the original means of activated carbon and after cleaning of the original image by AdAbSorb.

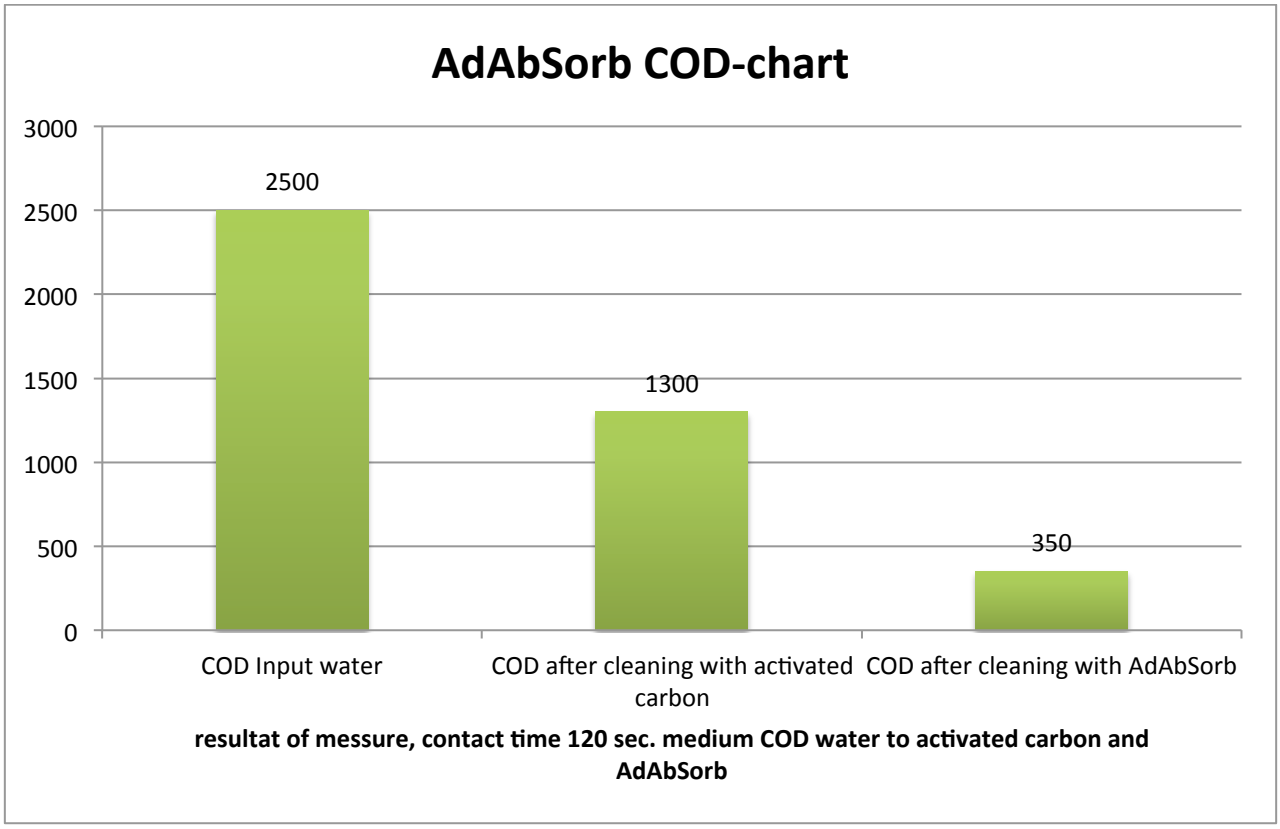
The chemical oxygen demand (COD) is a sum parameter and indicator of all organic compounds in the water, including the poorly degradable and non-biodegradable organic substances. The CSB is the amount of oxygen consumed for the oxidation of the whole water contained in the organic substances (dissolved and undissolved). The COD is expressed in mg O2 / l or g O2 / m^3. The CSB is also often used for determining the amount of sewage charges.

In the original sample is a polluted water with a COD of 2.500mgO2. The purified using activated carbon the original sample had still a COD of 1.300mgO2. The purified using AdAbSorb original sample had only a residual COD of 350mgO2.

The cleaning performance with respect to the COD corresponds to the activated carbon only 48%. In AdAbSorb even have 86% cleaning performance with respect to the COD are found.

AdAbSorb has demonstrably increased by 38% cleaning performance compared to the activated carbon.

The juxtaposition of the results is shown in the following graphic.



6 PRIMARY RESPONSIBILITIES IN PRACTICAL USE

The work focuses now in the practical testing and optimization for practical use. To this end, the Dr. Loeser & Ulbrich Umwelttechnik was carried out experiments with the different filling levels of the R & D department.

Furthermore, also be carried out tests on a real existing groundwater contamination in addition to the tests in the laboratory. In the groundwater damage a hoseskimmer is used to compare the two methods in terms of the absorbed oil and quantity of water in the same time periods directly with each other in addition to the AdAbSorb pads also for comparison.

7 DESCRIPTION OF THE TESTS

For the experiments in the laboratory of the Dr. Loeser & Ulbrich Umwelttechnik, a container was first filled with water and then waste oil was added from a garage on the water. There was an oil phase on the water.

There were taken individual subjects of the pads and filled with different amounts of AdAbSorb. The size of the individual subjects were 5cm x 44cm x 3cm (WxLxH) .The individual subjects had an empty weight of about 5gr. The filling was carried out with 55gr, 75gr, 95gr and 105gr. The loose bed gave a maximum filling of 110gr. These means that the compartments to approximately 50%, 70%, 85% and 95% were charged.

It was then measured by a precision balance, the amount of oil absorbed. To this end, this 1 minute has been suspended over the basin so that the adhesive on fabric oil could drip off before weighing the pads. After weighing, then the pad was suspended above the scale to be 5 minutes to drain the remaining unbound oil. This was done to the dripmeasurement in the ratio to the total amount of the captured oil to set, so that the results are not distorted by the material of the pads.

After the laboratory experiments, the same experiments were carried out in situ in the event of damage in a motor vehicle workshop. To this end, the concrete floor was cut open in the workshop in the abandoned waste oil cellar, so that the pads could be placed directly on the groundwater horizon. This groundwater is not reached when rising above the bottom plate, the water level was regulated by means of a pump.
This also has the side effect that constantly groundwater flowed into the area and thus the oil was mobilized on the ground and underneath the bottom plate.

Compared to the pads was created the same conditions at the same site at another location by means of a hoseskimmer and a submersible pump, as in the disused waste oil cellar. Here constantly the amount of absorbed oil-water mixture was measured. The two types of remediation a confrontation and a comparison of restoration are possible.

8 RESULTS

Following are the results of the laboratory experiment are shown and explained.

8.1 Compartment filled with 55 grams

The measuring range of the filled with 55gr times gave the following values.

Based on the values it can be seen that the main recording results within the first 0.5 h. After 3h is as good as done no more recording. The dripmeasurement is relatively constant. The intake of the oil is approximately 3 times its own weight of AdAbSorb. The filling level rose from about 50 vol.% To 75Vol.%. This means that an increase in volume of approximately 50% was carried out. The capacity of the AdAbSorb was thus not terminated by the limited volume of the fan. The adhesion and skin friction at the interface between AdAbSorb and the fabric can be neglected. The individual results of the series of measurements are tabulated.

Messreihe Aufnahme von Altöl auf Wasser								
Tara Wanne	650,8	Füllgewicht	55	Datum	05.03.2015	Tara Pad	58,96	
Zeit	Pad + Wanne	Abtropföl + Wanne	Ölaufnahme gesamt	Abtropföl	Ölaufnahme Pad / Zeitintervall	Ölaufnahme Pad	Ölaufnahme in Prozent	Ölaufnahme in Prozent / Minute
[min]	[gr]	[gr]	[gr]	[gr]	[gr]	[gr]	[%]	[%]
0	710	710	0	0	0	0	0	0
1	754	711	43	1	42	42	76,1	76,1
2	779	713	66	3	19	61	111,1	35,0
3	789	713	76	3	8	69	124,8	13,7
4	794	711	83	1	6	74	135,2	10,4
30	857	712	145	2	60	134	244,2	4,2
60	864	711	153	1	6	140	254,7	0,4
90	883	713	170	3	14	155	281,0	0,9
120	884	711	173	1	1	156	282,9	0,1
180	905	713	192	3	16	172	312,6	0,5
240	913	712	201	2	7	179	324,9	0,2
300	916	712	204	2	1	180	326,9	0,0
360	923	713	210	3	2	182	331,4	0,1
720	926	712	214	2	2	184	334,6	0,0
1790	926	712	214	2	0	184	334,6	0,0
4670	926	712	214	2	0	184	334,6	0,0

8.2 Compartment with 75 grams

The measuring range of the filled with 75gr times gave the following values.

Based on the values it can be seen that the main recording was not within the first 0.5 h, but in the time interval of 1 hour to 2 hours. The Dripmeasurement is relatively constant, but much higher as in the 55gr filling. The intake of the oil is approximately 6 times its own weight of AdAbSorb. The filling level rose from about 75Vol.% To 95Vol.%. This means that an increase in volume of approximately 30% was carried out. It is assumed that the maximum capacity has not been reached. This series of measurements is again driven again with a longer period of time. The capacity of the AdAbSorb was thus not terminatet by the limited volume of the fan. The adhesion and skin friction at the interface between AdAbSorb and the fabric can be neglected. The individual results of the series of measurements are tabulated.

Messreihe Aufnahme von Altöl auf Wasser								
Tara Wanne	684,66	Füllgewicht	75	Datum	05.03.2015	Tara Pad	80	
Zeit	Pad + Wanne	Abtropföl + Wanne	Ölaufnahme	Abtropföl	Ölaufnahme Pad / Zeitintervall	Ölaufnahme Pad	Ölaufnahme in Prozent	Ölaufnahme in Prozent / Minute
[min]	[gr]	[gr]	[gr]	[gr]	[gr]	[gr]	[%]	[%]
0	765	765	0	0	0	0	0	0
1	892	788	104	23	81	81	108,1	108,1
2	937	789	148	24	19	101	134,1	26,0
3	966	791	175	26	1	101	135,2	1,1
4	997	792	205	27	3	104	138,8	3,6
30	1066	795	271	30	35	139	185,9	1,8
60	1194	798	396	33	92	232	308,7	4,1
90	1302	801	501	36	69	301	400,7	3,1
120	1517	806	711	41	169	469	625,9	7,5

8.3 *Compartment filled with 95 grams*

The measuring range of the filled with 95gr times gave the following values.

Based on the values it can be seen that the main intake was within the first 5 minutes, then takes place as well as no more recording. The Dripmeasurement varies quite strong. Within the first 2 minutes, no oil is drained. From 2 minutes to 90 minutes, the Dripmeasurement is constant and very low. At 120 minutes to 180 minutes, the drained weight is quite high. The intake of the oil is approximately 2 times its own weight of AdAbSorb. The filling level rose from about 95Vol.% To 100Vol.%. Due to the absorption of the oil is to be assumed that the limited volume of the subject and the recording of the oil is reduced or restricted. It is also evident that the substance was tense. This means that the AdAbSorb would expand even further if the volume was not limited by the material. It is assumed that the maximum capacity is not yet reached, but was stopped by the volume limit. The individual results of the series of measurements are tabulated.

Messreihe Aufnahme von Altöl auf Wasser								
Tara Wanne	691,68	Füllgewicht	95	Datum	05.03.2015	Tara Pad	100	
Zeit	Pad + Wanne	Abtropföl + Wanne	Ölaufnahme	Abtropföl	Ölaufnahme Pad / Zeitintervall	Ölaufnahme Pad	Ölaufnahme in Prozent	Ölaufnahme in Prozent / Minute
[min]	[gr]	[gr]	[gr]	[gr]	[gr]	[gr]	[%]	[%]
0	792	792	0	0	0	0	0	0
1	949	792	158	0	158	158	166,1	166,1
2	952	792	160	0	3	160	168,8	2,7
3	960	792	168	1	7	167	175,7	7,0
4	971	792	179	1	11	178	186,9	11,2
5	979	791	188	-1	10	187	197,0	10,1
6	996	796	200	4	8	195	205,5	8,5
7	1011	798	212	7	6	201	211,7	6,2
8	1027	802	225	10	2	203	213,9	2,2
9	1054	806	248	14	9	213	223,7	9,9

8.4 Compartment with 105 grams

The measuring range of the filled with 105gr times gave the following values.

Based on the values it can be seen that the main intake was within the first minute. After 4 minutes, took place as well as no more recording. The Dripmeasurement constantly increases after the first minute. The intake of the oil is approximately 70% of its own weight of AdAbSorb. The filling level was also at the beginning of the measurement series 100Vol.%. Due to the absorption of the oil is to be assumed that the limited volume of the subject and the recording of the oil is reduced or restricted. It is also evident that the substance was tense. This means that the AdAbSorb would expand even further if the volume was not limited by the material. It is assumed that the maximum capacity is not yet reached, but was stopped by the volume limit. This also shows the constant increase of the Dripmeasurement. The AdAbSorb has thus lost its absorbency by the volume limit. Only the adsorption has taken oil to some extent. The individual results of the series of measurements are tabulated on the next page.

Messreihe Aufnahme von Altöl auf Wasser								
Tara Wanne	688,01	Füllgewicht	105	Datum	05.03.2015	Tara Pad	110	
Zeit	Pad + Wanne	Abtropföl + Wanne	Ölaufnahme	Abtropföl	Ölaufnahme Pad / Zeitintervall	Ölaufnahme Pad	Ölaufnahme in Prozent	Ölaufnahme in Prozent / Minute
[min]	[gr]	[gr]	[gr]	[gr]	[gr]	[gr]	[%]	[%]
0	798	798	0	0	0	0	0	0
1	850	806	44	9	35	35	33,7	33,7
2	895	817	78	19	15	50	47,8	14,1
3	920	818	101	20	3	53	50,8	3,0
4	973	830	143	32	9	63	59,8	9,0
5	1038	843	194	45	6	69	65,9	6,1
6	1111	857	254	59	1	70	67,0	1,1
7	1175	859	316	61	1	71	68,0	0,9
8	1247	864	383	66	1	72	69,0	1,1
9	1320	867	453	69	0	73	69,2	0,2

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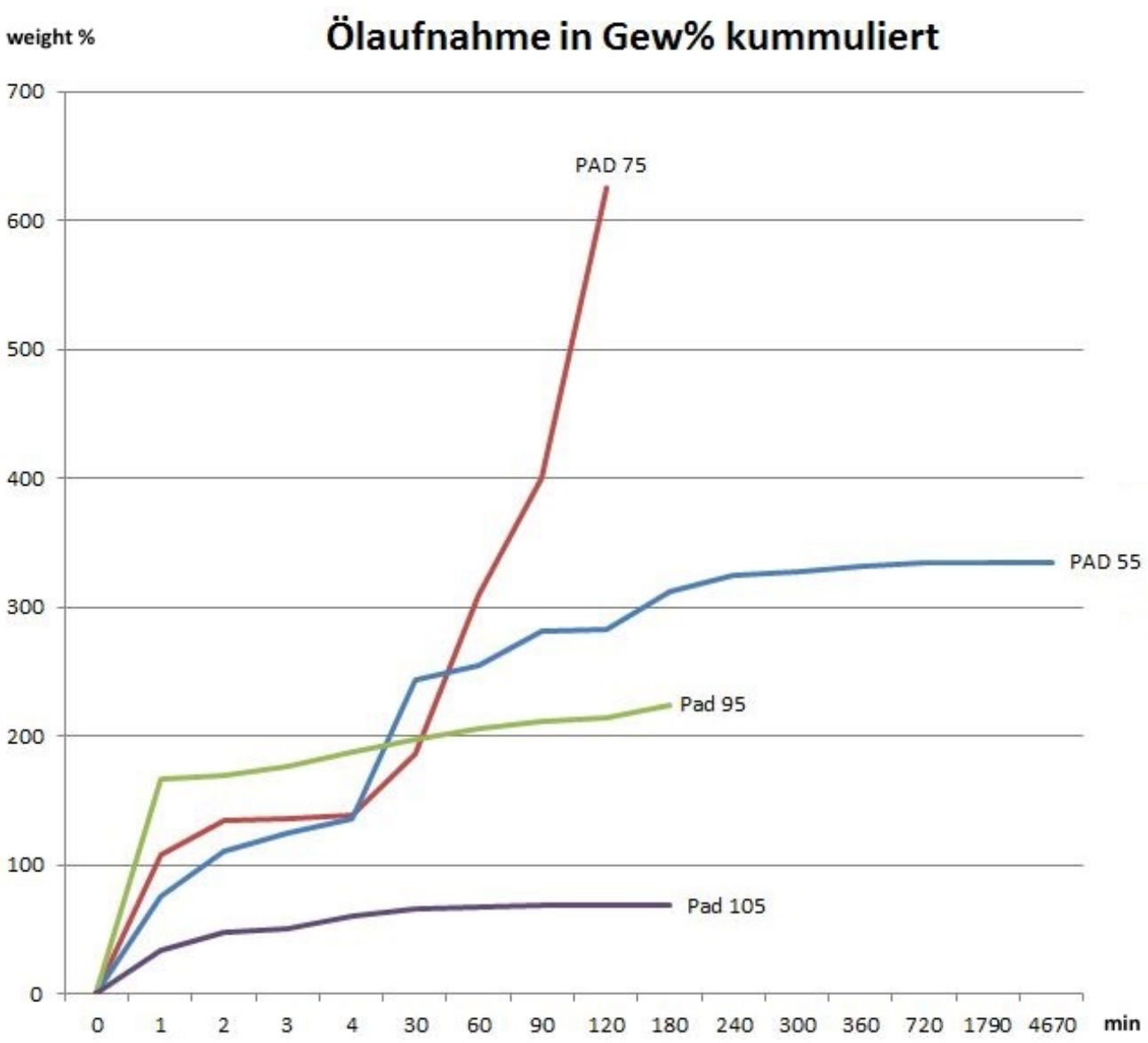

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9 ABSORPTION RATELIST OF DIFFERENT CHEMICALS

Absorption capacuty from AdAbSorb vs. activated carbon*					
Index	Substanz	Absorption in weight % **			Faktor** more absorption from AdAbSorb
		AdAbSorb	Standart activated carbon	AdAbSorb to A-carbon	
A	Acetone	342%	16%	2138%	21
	Ammonia con.	210%	10%	2100%	21
	Ant acid	301%	16%	1881%	19
B	Gasoline E95	533%	30%	1777%	18
	Gasoline E10	640%	30%	2133%	21
	Benzol	632%	30%	2107%	21
	Butylacetat	355%	30%	1183%	12
	Butylalcohol	257%	30%	857%	9
D	1,4 Dioxan	369%	30%	1230%	12
E	Acetic acid	268%	30%	893%	9
	Acetic acid ethylester	483%	30%	1610%	16
	Ethanol	304%	30%	1013%	10
	Ethylglykol	299%	30%	997%	10
M	Methanol	337%	16%	2106%	21
N	n- Propanol	318%	30%	1060%	11
	p- cresol	220%	30%	733%	7
	Pyridin	409%	30%	1363%	14
S	Lubricant	374%	30%	1247%	12
	Nitric acid con.	267%	30%	890%	9
	Sulphuric acid con.	538%	30%	1793%	18
T	Creosote	420%	30%	1400%	14
	Toluol	252%	27%	933%	9
X	Xylol	189%	38%	497%	5

* Average empirical values ** Rounded values

All information is without guarantee, as each project requires a case study and laboratory tests

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Substance	absorption in grams per 100g AdaBSorb
Acetone	342
Ammonia con.	210
Ant acid	301
Gasoline N	533
Gasoline S	640
Butylacetat	355
Butylalcohol	257
Diesel fuel	458
1,4 Dioxane	369
Acetic acid	268
Acetic acid ethylester	483
Ethanol	304
Ethylglykol	299
Ethylenglykol	295
Glycerin	233
Heat oil	434
Linen oil	320
Methanol	337
Maschinen oil BP	401
Maschinen oil neu	457
Maschinen oil gebr.	408
n- Propanol	318
Sodium hydroxide 33 %	299

Substance	absorption in grams per 100g AdaBSorb
Olive oil	321
p- Kresol	220
1,2 Propylenglykol	226
Paraffins	321
Pyridin	409
Vegetable oils	316
Phtal acid dibutylester	315
Rape oil	402
Castor oil	444
Crude Döbern	404
Crude Tauer	345
Crude Lütow	438
Crude Russian Blend	402
Lubricate oil	374
Soya oil	398
Sun Flowers oil	220
Salt acid con.	258
Nitric acid con.	267
Sulphur acid con.	538
Tar oil	420
Generator-Transformer oil	435
Tetrahydrofuran	546
Solvent mixture	610

10 SUMMARY

AdAbSorb is very suitable for the rehabilitation of oil spills in the area of water or groundwater.

The AdAbSorb pads are buoyant and hydrophobic. The AdAbSorb is a hydrophobic and lipophilic adsorbing adsorbent for lipophilic substances. The capacity of the AdAbSorb is strongly dependent on the filling level of the individual compartments of the pads. The optimum filling level of the individual subjects is approximately 75Vol%. In this filling the material does not slip so much and the remaining volume is sufficient for the volume increase of AdAbSorb from.

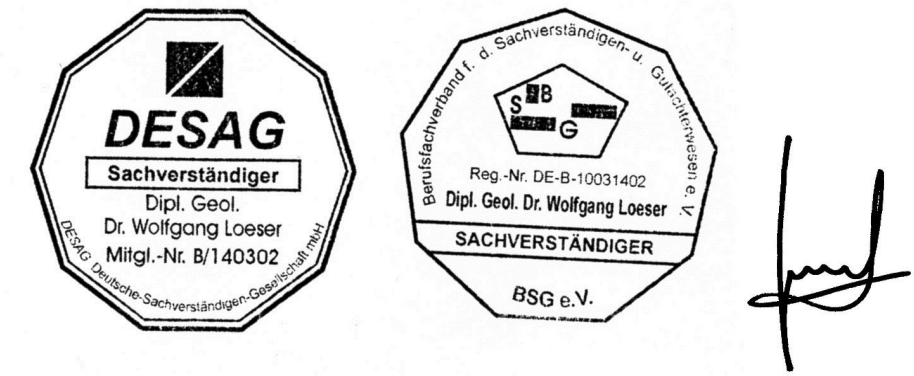
The AdAbSorb adsorbed first quite fast, the lipophilic substances and absorbed then. In the absorption, the volume increase takes place. Due to absorption, the surface is free again for the adsorption of lipophilic substances. Due to the absorption the lyophilic substances are no longer released to print. Due to this circumstance, the handling and transport of laden AdAbSorb pads are fairly simple.

When disposing of the good results in fact that the AdAbSorb can also be used as an energy supplier. A use as an energy source would be the plant for thermal recycling of residual waste or as an energy source in the cement industry in the field of co-firing.

Since the AdAbSorb is no oil binder in the conventional sense and therefore also not lead to a rearrangement of the oil in the water due to a falling oil binder and AdAbSorb can also serve as an energy source, it is currently the most effective and ecologically sound nature of the remediation of oil spills on waters.

Another application would be as a filter system for rainwater to clean rainwater, contaminated with lipophilic substances. Due to the preliminary examinations of the Institute of Environmental Engineering of the University of Bremen is also known that AdAbSorb is suitable for the purification of water, which is contaminated with PCBs or BTX.

AdAbSorb is a very good adsorbent absorber for the purification of water contaminated with lipophilic substances, PCBs and BTX in water.



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