[Proceeding] Assessing the performance of combination particulate and gaseous contaminant air filters

FILTECH 2007
CONFERENCE PROCEEDINGS
VOLUME II

CONTENT VOLUME I **L-Sessions**

CONTENT VOLUME II **G-Sessions**
M-Sessions

Conference Dates:
February 27 - March 1, 2007

Venue:
Rhein-Main-Hallen · Rheinstr. 20 · 65028 Wiesbaden · Germany

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SESSION SURVEY

Tuesday, February 27, 2007			
8.30 – 9.45	**Registration**		
9.45 – 11.30	**Opening Session/Plenary Lecture**		
11.30 – 12.15	**Walk Around - Exhibition**		
12.15 – 13.15	**Lunch**		
13.15 – 14.30	**L1** Selection and Specification of Filter Equipment and Filter Media	**L4** Influence of Physico/ Chemistry on Filtration	**G1** Surface Filtration I
15.00 – 16.15	**L2** Cake Filtration Fundamentals	**L5** Influence of Chemicals or Magnetic Forces on Cake Filtration	**G2** Surface Filtration II
16.45 – 18.00	**L3** Simulation of Filter Cake and Filter Media Structure	**L6** Suspension Characterization by Sedimentation Analysis	**G3** Measurement Techniques

Wednesday, February 28, 2007			
8.30 – 9.45	**L7** Pore Structure Measurement	**M1** Ultrafiltration	**G4** Electrostatic Precipitation
10.15 – 11.30	**L8** Poster Session L–I	**M2** Poster Session M–I	**G5** Poster Session G–I
11.30 – 12.15	**Poster Session**		
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13.15 – 14.30	**L9** Developments in Dynamic Cake Filtration	**M3** Simulation, Control, Design	**G6** Fibrous Filter I
15.00 – 16.15	**L10** Developments in Pressure Filtration	**M4** Water Treatment and Reverse Osmosis	**G7** Fibrous Filter II
16.45 – 18.00	**L11** Hydrocyclones	**M5** Gas Separation	**G8** Modelling and Simulation

Thursday, March 1, 2007			
8.30 – 9.45	**L12** Biofilms - Fouling - Cleaning Procedures	**M6** Separation of Complex Systems	**G9** Industrial Gas Cleaning
10.15 – 11.30	**L13** Depth Filtration Removal of Pollutions from Liquids	**M7** Poster Session M-II	**G10** Poster Session G–II
11.30 – 12.15	**Poster Session**		
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13.15 – 14.30	**L14** Depth Filtration - New Fibrous Media and Fiber Structuring	**M8** Membrane Bio Reactor	**G11** Filter Test Systems I
15.00 – 16.15	**L15** Depth Filtration and Microflotation for Water Treatment	**L18** Vacuum Filtration and Tailings Processing	**G12** Filter Test Systems II
16.45 – 18.00	**L16** Flocculation/Coagulation for Waste Water Treatment	**L17** Particle Size Analysis for Solid-Liquid-Separation Processes	**G13** New Filter Media

TUESDAY, 27.02.2007

Opening Session and Plenary Lecture 09:45-11:30

Plenary Lecture "The Kinetics of Dust Filtration", Prof. Dr. Gerhard Kasper, University of Karlsruhe, Germany

L1 Selection and Specification of Filter Equipment and Filter Media 13:15-14:30

Computer software for the simulation of solid/liquid separation equipment, *E. S. Tarleton*, R. Wakeman, Loughborough University, Great Britain* **(I–11)**

About 20 years of operation experience of wastewater filtration in Germany, *M. Barjenbruch*, Technical University of Berlin; T. Rolfs, Wasserverband Eifel-Rur, Germany* **(I–19)**

Researches regarding the accomplishing of filtering products meant for air and water pollution prevention, *N. Gheorge*, E. Visileanu, B. Niculina, National Institute for Textile and Leather, Romania* **(I–28)**

L4 Influence of Physico/ Chemistry on Filtration 13:15-14:30

Effects of ion specific adsorption on filtration performance, *S. Biggs*, R. Nabi, C. Poole, University of Leeds; D. Hebditch, G. Baker, W. Clark, British Nuclear Group, Great Britain* **(I–87)**

Influence of salt concentration on the rheological properties during filtration of aqueous anorganic suspensions, *M. Hieke*, H. Nirschl, University of Karlsruhe, Germany* **(I–97)**

Influence of particle charge on the filtration of nanoparticulate suspensions and on the permeation of the obtained filter cakes, *B. Schäfer*, H. Nirschl, University of Karlsruhe, Germany* **(I–104)**

G1 Surface Filtration I 13:15-14:30

Particulate emissions caused by leaks in surface filters for dust separation, *B. Bach*, E. Schmidt, University of Wuppertal, Germany* **(II–11)**

The influence of the fibre cross-sectional form on the fractional particle penetration for cleanable dust filter media, *H. Rud*, G. Mauschitz, W. Höflinger, Vienna University, Austria* **(II–19)**

On the origin and the mechanisms of dust emission from pulse-jet cleaned filter media, *J. Binnig*, J. Meyer, G. Kasper, University of Karlsruhe, Germany* **(II–27)**

L2 Cake Filtration Fundamentals 15:00-16:15

Exploring the parabolic – Asymptotic transition in cake filtration and compression, *R. G. de Kretser*, P. J. Scales, A. Stickland, S. P. Usher, J. Lim, University of Melbourne, Australia* **(I–37)**

Modelling Filtration Through Woven Fabrics, *M. A. Nazarboland*, X. Chen and J.W.S. Hearle, University of Manchester; R. Lydon, M. Moss, Clear Edge Group, Great Britain* **(I–45)**

Macroscopic flow phenomena and microscopic surface properties affecting filter cake washing, *F. Ruslim*, H. Nirschl, W. Stahl, University of Karlsruhe, Germany; P. Carvin, RHODIA - Research Center of Lyon, France* **(I–53)**

L5 Influence of Chemicals or Magnetic Forces on Cake Filtration 15:00-16:15

Mechanical dehydration and drying of mineral suspensions in presence of dispersant, *O. Larue*, A. Dusanter, E. Vorobiev, K. Saleh, P. Guigon, University of Compiègne, France* **(I–112)**

Magnetic fields in particle technology and processing, *M. Stolarski*, C. Eichholz, B. Fuchs, H. Nirschl, University of Karlsruhe, Germany* **(I–121)**

Magnetic field enhanced cake filtration of superparamagnetic nanocomposites, *C. Eichholz*, M. Stolarski, V. Goertz, H. Nirschl, University of Karlsruhe, Germany; B. Fuchs, DuPont PARSAT, USA* **(I–133)**

G2 Surface Filtration II 15:00-16:15

Particle deposition in the depth of nonwoven dust filter media and its effect on filter clogging, *G. Mauschitz*, H. Rud, W. Höflinger, Vienna University, Austria* **(II–34)**

Conditioning of filter bags with reactive CaO and Ca(OH)2 dust in flue gas, *M. Koch*, NTNU Norwegian University of Science and Technology, Norway; M. Saleem, P. Pucher, G. Krammer, Graz University, Austria* **(II–42)**

Effect of cake residence time on the regeneration efficiency of surface filters at high temperatures, *N. Döring*, J. Meyer, G. Kasper, University of Karlsruhe, Germany* **(II–5)**

L3 Simulation of Filter Cake and Filter Media Structure 16:45-18:00

Computer simulation of filter cake structure, *J. Dueck*, T. Neesse, University Erlangen-Nuremberg, Germany; E. Diatschenko, L. Minkov, Tamsk State University, Russia* **(I–62)**

Design of fibrous filter media based on the simulation of pore size measures, *J. Becker*, A. Wiegmann, V. Schulz, Fraunhofer Institute for Industrial Mathematics ITWM, Germany* **(I–71)**

Computational study of pressure drop dependence on pleat shape and filter media, *A. Wiegmann*, S. Rief, D. Kehrwald, Fraunhofer ITWM, Germany* **(I–79)**

L6 Suspension Characterization by Sedimentation Analysis 16:45-18:00

Characterization of interparticle forces for solid-liquid separation processes using multisample analytical centrifugation, *T. Sobisch*, D. Lerche, L.U.M. GmbH, Germany* **(I–142)**

Comparison of particle separation in centrifuges with cylindrical tubes or disc rotors. Experiments and theoretical models, *D. Lerche*, T. Sobisch, L.U.M. GmbH, Germany* **(I–150)**

Fine particles separation in recovered paper suspensions, *J. Wagner*, Darmstadt University; S. Schabel, H. Nirschl, University of Karlsruhe, Germany* **(I–158)**

G3 Measurement Techniques 16:45-18:00

The effect of filter tester geometry on cleaning pulse intensity , *J. Binnig*, A. Bredin, J. Meyer, G. Kasper, University of Karlsruhe, Germany* **(II–58)**

Filter test with soot generation from 7.5 nm up to 200

nm, *G. Lindenthal*, L. Mölter, PALAS GmbH, Germany* **(II–66)**
Experimental examination of the sublimation of submicron volatile particles, *A. Breidenbach*, F. Schmidt, M. Winterer, University of Duisburg-Essen, Germany* **(II–74)**

WEDNESDAY, 28.02.2007

L7 Pore Structure Measurement 8:30-9:45

Homogeneity of pore structure characteristics of filtration cartridges, *K. Gupta*, K. Jena, PMI Inc, USA* **(I–165)**

Challenge testing by precision glass microspheres – a new physical method of measuring pore sizes, *G. R. Rideal*, J. Storey, Whitehouse Scientific, Great Britain* **(I–173)**

Electrical resistance tomography in thermally assisted mechanical dewatering processes, *A. Mahmoud*, A. Fernandez, P. Arlabosse, Ecole des Mines d'Albi-Carmaux, France* **(I–181)**

M1 Ultrafiltration 8:30-9:45

Cross-flow ultrafiltration of high molecular weight polymer, *L. Beguin*, H. Duval, M. Rakib, Ecole Centrale Paris, France* **(II–384)**

Innovative technologies in water treatment based of ultrafiltration, *T. Peters*, Dr.-Ing. Peters Consulting for Membrane Technology, Germany* **(II–392)**

Ultrafiltration membranes in conjunction with functional water-soluble polymers to remove metal ions, *B. L. Rivas*, A. A. Pooley, E. Pereira, A. Maureira, University of Conception, Chile* **(II–400)**

G4 Electrostatic Precipitation 8:30-9:45

Soot separation in a modified pipe electrostatic precipitator, *M. Horn*, University of Erlangen Nuremberg; H.-J. Schmid, University Paderborn, Germany* **(II–81)**

Collection of ultra-fine aerosol in a novel wet electrostatic precipitator with high intensity ionizing stage, *A. Bologa*, H.-R. Paur, H. Seifert, K. Woletz, Forschungszentrum Karlsruhe, Germany* **(II–89)**

Advanced electrostatic fabric filter system, A new concept for air toxic and fine-particulate control, *Y.-O. Park*, H. Y. Choi, J. H. Lim, Korea Institute of Energy Research, Korea* **(II–97)**

L8 Poster Session L-I 10:15-11:30

Optical measurement of oil contamination, *H. Sauter*, H. Richter, T. Häusle, Mahle GmbH, Germany* **(I–191)**

Modeling and dyn,amical simulation of the sedimentation of solid-liquid suspensions, *J. J. R. Damasceno*, F. O. Arouca, L. C. Oliviera-Lopez, Federal University of Uberlandia, Brazil* **(I–199)**

Evaluation of the accommodation of particles and the initial settling velocity in solid-liquid systems based on the physical properties of solid particles, *J. J. R. Damasceno*, F. O. Arouca, F. S. Amaral, M. C. Fontes, Federal University of Uberlandia, Brazil* **(I–207)**

About validation of liquid filter efficiency test stands, *C. Peuchot*, N. Petillon, I.F.T.S. Institute of Filtration and Separation, France* **(I–216)**

A new method to determine particulate filtration efficiency of submicron cartidge filters, *C. Peuchot*, N. Petillon, I.F.T.S. Institute of Filtration and Separation, France* **(I–228)**

Correlation between fineness of malt grist and particle size on the conversion during mashing and filtration process, *J. Tippmann*, J. Voigt, K. Sommer, Technical University Munich Weihenstephan, Germany* **(I–237)**

M2 Poster Session M-I 10:15-11:30

Particle blocking and deposition in polymeric membrane in cross-flow microfiltration, *K.-J. Hwang*, H.-S. Chiu, S.-F. Wu, Tamkang University, Taiwan* **(II–404)**

Effect of deformability of soft particles on the fouling mechanism of crossflow microfiltration, *K.-L. Tung, C.-C. Hu, C.-J. Chuang, Chung Yuan Christian University, Taiwan; W. Chen, Dow Chemical Co., USA* **(II–412)**

An improvement of cross-flow microfiltration, *R. M. Wu*, K.-J. Lee, H.-H. Fang, C.-Y. Hsu, Tamkang University, Taiwan* **(II–419)**

The influence of Na+ and Mg2+ on the microfiltration process of titanium dioxide dispersion, *P. Velikovska*, P. Mikulasek, University of Pardubice, Czech Republic* **(II–427)**

Effect of transmembrane pressure and centrifugation on crossflow microfiltration of bovine milk, *M. L. Gimenes*, R. C. de Oliveira, S.T. D. de Barros, F. A. F. Alvim, J. C. B. Faria, State University of Maringá, Brazil* **(II–433)**

Hybrid biosorbent: an innovative matrix to remove Cd(II) from aqueous solution, *M. Iqbal*, A. Saeed, Biotechnology and Food Research Centre, Pakistan* **(II–447)**

G5 Poster Session G-I 10:15-11:30

Balance refill unit for continuous dust dosage enables long term tests, *S. Schütz*, Palas GmbH, Germany* **(II–107)**

Industrial portable filtertest technology, *F. Schneider*, Grimm Aerosol-Technik GmbH, Germany* **(II–114)**

Non-contact measurements of dust distribution and cake thickness on air filter media, *T. Häusle*, H. Sauter, Mahle GmbH, Germany* **(II–121)**

Gas filtration with celulose fiber filtering media, *M. L. Aguiar*, V. M. Osorio, D. F. Torre, E. R. Tognetti, K. B. Rodriguez, Federal University of Sao Carlos, Brazil* **(II–128)**

Influence of the operational conditions on the formation and detachment of the cake on gas-solid filtration, *M. L. Aguiar*, E. R. Tognetti, P. A. Paschoal, V. M. Osorio, Federal University of Sao Carlos, Brazil* **(II–136)**

The application of catalytic filter media for the removal of multiple pollutants from process waste gas, *A. Startin, Madison Filter Ltd., Great Britain* **(II–144)**

Collection efficiency of a polyester filter, operating on the removal of nano-sized aerosol particles, *V. G. Guerra*, J. Steffens, J. R. Coury, Federal University of Sao Carlos, Brazil* **(II–152)**

Deposition of nanoparticles in the composites of nano- and microsized fibers, *R. Przekop*, L. Gradon, University of Warsaw, Poland* **(II–160)**

Low pressure plasma for nanocoatings on nonwoven materials for filtration and separation, *M. Pauwels*, Europlasma N.V., Belgium* **(II–168)**

L9 Developments in Dynamic Cake Filtration 13:15-14:30

Effects of media filter inlet design on bed surface deformation and grade efficiency, *D. B. Ward*, Industrial Purification Systems Ltd.; R. J. Poole, I. Owen, University of Liverpool, Great Britain* **(I–243)**

Development and technical upgrade of mash filtration with thin-layer chamber mash filter (TCM) in combination with fine wet milling with a rotor/stator system (RSS) for brewing technology, *H.-J. Menger*, Ziemann Ludwigsburg GmbH, Germany* **(I–252)**

The application of the double cylindrical filter press to the sewage sludge treatment, *D. Takao*, K. Neo, T. Murasawa, M. Ono, Tsukishima Kikai Co. Ltd., Japan* **(I–260)**

M3 Simulation, Control, Design 13:15-14:30

Hydrodynamic optimisation of a membrane bioreactor for waste water treatment, *H. Prieske*, A. Drews, M. Kraume, Technical University of Berlin, Germany* **(II–456)**

Model-based control of membrane filtration processes, *J. Busch*, W. Marquardt, RWTH Aachen University, Germany* **(II–464)**

Modeling of flux decline for dead-end ultrafiltration of water contaminated with escherichia coli, *M. H. M. Reis*, R. M. Ribeiro, R. Bergamasco, State University of Maringa; M. R. Wolf-Maciel, State University of Campinas, Brazil* **(II–473)**

G6 Fibrous Filter I 13:15-14:30

Single fiber efficiency and built-up of the particulate structures on single dust-loaded fibers, *S. Schollmeier*, J. Meyer, H. Umhauer, G. Kasper, University of Karlsruhe, Germany* **(II–175)**

Performance of commercial and prototype fibrous media measured with different test aerosols, *A. Rochereau*, L. Le Coq, A. Subrenat, P. Le Cloirec, Ecole des Mines de Nantes, France* **(II–185)**

Theoretical and experimental study on the most penetrating size of aerosol particles in fibrous filters, *A. Balazy*, A. Podgorski, Warsaw University, Poland* **(II–192)**

L10 Developments in Pressure Filtration 15:00-16:15

Advanced filtration of PTA (Pure Terephthalic Acid): separation, washing and demoisturing in a single process unit with hi-bar filtration, *R. Bott*, T. Langeloh, M. Schießl, Bokela GmbH, Germany* **(I–268)**

Improved design & performance of sterile agitated nutsch filter-dryer - BASP CRYSTAL PROCESSOR, *B. Patil*, V. Patil, BASP Industries, India* **(I–276)**

Intensified processes in solid-liquid separation on rotary pressure filters, *J. Tichy*, BHS-Sonthofen GmbH; S. Ripperger, K. Nikolaus, University of Kaiserslautern, Germany* **(II–284)**

M4 Water Treatment and Reverse Osmosis 15:00-16:15

Improving seawater desalination with reverse osmosis, *T. Peters*, Dr.-Ing. Peters Consulting for Membrane Technology, Germany* **(II–481)**

Investigations of silica scaling on reverse osmosis membranes, *G. Braun*, M. Graczyk, T. Harrer, University of Applied Science Cologne; W. Hater, C. zum Kolk, C. Dupoiron, Henkel KGaA, Germany* **(II–489)**

Membrane charge measurement for industrial applications, *K.-L. Tung, C.-C. Hu, C.-J. Chung, Chung Yuan Christian University, Taiwan; W. Chen, Dow Chemical Company, USA* **(II–497)**

G7 Fibrous Filter II 15:00-16:15

Depth and surface aerosol filtration in nanofibrous media, *A. Podgorski*, A. Balazy, L. Gradon, Warsaw University, Poland* **(II–200)**

The function of submicron and nanofibers in engine air filtration, *T. Jaroszczyk*, S. L. Fallon, T. P. Sonsalla, Cummins Filtration Inc, USA* **(II–208)**

Assessing the performance of combination particulate and gaseous contaminant air Filters, *P. Tronville*, Polytechnic University of Torino, Italy; R. D. Rivers, EQS Inc, USA* **(II–219)**

L11 – Hydrocyclones 16:45-18:00

Analysis of the geometric relationships influence in the performance of hydrocyclone, *J. J. R. Damasceno*, M. A. Barrozo, L. G. M. Vieira, C. A. Silva Jr., B. C. Silveiro, Federal University of Uberlandia, Brazil* **(I–291)**

Effect of vortex and apex on purification process of bentonite with hydrocyclone for producing nanoclay, *M. Nasiri Sarvi*, M. Oliazadeh, S. Bazgir, University of Tehran, Iran* **(I–299)**

Optimization of the solid-liquid separation in the filtering hydrocyclones, *J. J. R. Damasceno*, M. A. Barrozo, L. G. M. Vieira, C. A. Silva Jr., B. C. Silveiro, Federal University of Uberlandia, Brazil* **(I–305)**

M5 Gas Separation 16:45-18:00

Polyaniline nano-membranes for gas separations – structure and performance, *R. Wakeman*, Y. Gupta, University of Loughborough; K. Hellgardt, Imperial College of Science London, Great Britain* **(II–505)**

Carbon dioxide absorption in hollow fibre membrane modules, *A. A. Elamari*, Altahadi University, Libya* **(II–513)**

G8 Modelling and Simulation 16:45-18:00

A Semi-analytical model for fluid flow in high efficiency pleated filters for gas filtration, *M. Rebai*, M. Prat, IMFT - Institut de Méchanique des Fluides de Toulouse; M. Meireles, Université Paul Sabatier; P. Schmitz, INSA - Institut National des Sciences Appliquées; R. Baclet, S. Demeulemeester, Mecaplast Group, France* **(II–227)**

Prediction of pressure drop and filtration efficiency of fibrous filters by calculation with a cell model on the basis of single fiber efficiency data, *S. Schollmeier*, J. Hoferer, J. Meyer, G. Kasper, University of Karlsruhe, Germany* **(II–235)**

Coupling CFD and filtration models to describe the long-term behaviour of DPF, *U. Janoske*, University of Cooperative Education Mosbach; T. Deuschle, M. Piesche, University Stuttgart, Germany* **(II–239)**

THURSDAY, 01.03.2007

L12 Biofilms – Fouling – Cleaning Procedures 8:30-9:45

Using oxygen consumption rate and atp assay to evaluate biofilm activity, *L.-F. Chen*, Shu-Te University, Taiwan; J. S. Vrouwenvelder, D. van der Kooij, KIWA N.V., Netherlands; W. L. Lai, Ta-Jen University, Taiwan* **(I–312)**

Performance of textile filtration materials as a replacement for membranes in membrane bioreactors (MBRs), *A. Drews*, V. Iversen, T. Schmidt, M. Kraume, University of Berlin; B. Lesjean, Berlin Centre of Competence for Water, Germany* **(I–320)**

The cleaning behaviour of filter media for applications in the solid-liquid-separation, *S. Stahl*, H. Nirschl, University of Karlsruhe, Germany* **(I–327)**

M6 Separation of Complex Systems 8:30-9:45

New application for membrane filtration in the production of natural gas , *J. Schmidt*, M. Ritter, C. Bohner, Enviro Chemie GmbH; H. Reyneke, Linde AG, Germany; R. E. Jensen, Statoil ASA, Norway* **(II–523)**

Regeneration of organic solvents and valuable components by membrane separation, *P. Cuperus*, SolSep b.v., Belgium* **(II–529)**

Rejection characteristics and flux recovery of BSA solutions in inorganic membrane filtration, *T.-W. Cheng*, P.-M. Li, Tamkang University, Taiwan* **(II–535)**

G9 Industrial Gas Cleaning 8:30-9:45

Star-BagsTM - Application of an advanced filter media construction for greater filtration and production efficiency, *M. Neate*, B. Currell, P. Bowden, Albany International Pty Ltd., Australia* **(II–245)**

Novel approaches to prevent candle filter failure in dry cleaning of syngas derived from coal gasification, *S. D. Sharma*, A Ilyushechkin, N. Kinaev, K. McLennan, M. Dolan, T. Nugyen, D. Park, CSIRO Energy Technology, Australia; R. S. Dahlin, Southern Research Institute, USA* **(II–253)**

Spunlaced nonwovens – an advantageous alternative for filtration media, *V. Lorentz*, Norafin GmbH, Switzerland* **(II–262)**

L13 Depth Filtration Removal of Pollutions from Liquids 10:15-11:30

Study of filter media to remove bacteria from water, *M. L. Gimenes*, R. Bergamasco, O. A. A. Santo, C. V. Nakamura, F. V. Silva, L. P. Martins, E. C. Martins, Maringá State University, Brazil* **(I–334)**

The loading of liquid filter media, *H. Banzhaf*, M. Lehmann, G.-M. Klein, Mann + Hummel GmbH, Germany* **(I–341)**

Organic fluorescent property and bacterial activity of effluent from biofilter, *W.-L. Lai*, S.-W. Liao, S.-L. Hsu, C.-Y. Chiu, Y.-T. Lee, Ta-Jen University; L.-F. Chen, Shu-Te University, Taiwan* **(I–349)**

M7 Poster Session M-II 10:15-11:30

Polymeric membranes for organophilic nanofiltration, *T. Beeskow*, GMT Membrantechnik GmbH; J. Stegger, Borsig Membrane Technology GmbH, Germany* **(II–543)**

Preparation and characterization of NF composite membrane by photografting method, *S.-H. Chen*, R.-M. Liou, J.-S. Chang, Chia-Nan University; J. Y. Lai, Chung Yuan University; D. J. Chang, The Overseas Chinese Institute of Technology, Taiwan* **(II–547)**

Application of ceramic and polymer membranes for treatment of defined process wastewater in textile finishing, *J. Hildenbrand*, T. Quadt, A. Rabhi, E. Schmidt, J. Marzinkowski, University of Wuppertal, Germany* **(II–557)**

Effect of ion exchanged properties on the separation performance of polysulfone/acrylic acid ultrafiltration membrane, *S.-H. Chen*, H.-C. Ho, R.-M. Liou, J. S. Chang, Chia-Nan University; D. J. Chang, The Overseas Chinese Institute of Technology, Taiwan* **(II–564)**

The performance of hydrophobile woven meshes in the fuel-water separation applications, *P. Massini*, M. Mietta, L. Napoli, Saati S.p.A., Italy* **(II–440)**

Lactose production from whey permeate, *M. L. Gimenes*, R. R. Souza, R. Bergamasco, S. C. Costa, Maringá State University, Brazil* **(II–572)**

Ultrafiltration after coagulation/flocculation process to obtain potable water, *M. L. Gimenes*, L. C. K. Moraes, R.* **(II–580)**

G10 Poster Session G-II 10:15-11:30

Influence of droplet size in the collection efficiency of a venturi scrubber with multiple orifice injection, *V. G. Guerra*, J. R. Coury, K. C. Corali, A. P. R. A. Ribeiro, J. A. S. Goncalves, Federal University of Sao Carlos, Brazil* **(II–264)**

Dielectric barrier discharge arrangement for air disinfection, *V. Ermel*, M. Kurrat, Technical University Braunschweig, Germany* **(II–273)**

Experimental investigation of filtration efficiency and pressure drop of surgical face mask and nanofiber filter, *W. Leung*, C. Tsang, C.-H. Hung, Hong Kong Polytechnic University, Hong Kong* **(II–612)**

Cleaning characteristics of new one-touch pleated filter bags, *J. H. Lim*, Y.-O. Park, K. S. Lim, KIER - Korea Institute of Energy Research, Korea* **(II–279)**

Nanospider technology and filtration, *D. Stranska*, ELMARCO s.r.o., Czech Republic* **(II–287)**

Axial flow cyclone to remove nanoparticles at low pressure conditions, *R. Przekop*, A. Moskal, L. Gradon, Warsaw University, Poland; C.-J. Tsai, S.-C. Chen, National Chiao-Tung University, Taiwan* **(II–290)**

Effect of the conic part length and particle exit diameter on the cyclone performance, *J. J. R. Damasceno*, A. F. Lacerda, M.A.S. Barrozo, Uberlandia University, Brazil* **(II–298)**

Treatment of electric arc furnace dust prior to permanent disposal, *V. Orescanin*, L. Mikelic, S. Lulic, Institute Rudjer Boskovic; T. Sofilic, Sisak Tube Mill Ltd.; G. Medunic, A. Rastovcan-Mioc, University of Zagreb; L. Elez, Ministry of Culture-Administration for Protection of Nature, Croatia* **(II–306)**

Modeling of an air classifier system with the flow chart simulation tool SolidSim, *D. Nitschke*, E. Schmidt, University of Wuppertal, Germany* **(II–314)**

L14 Depth Filtration – New Fibrous Media and Fiber Structuring 13:15-14:30

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Linking duty and media in hydraulic oil filtration, *H. Kleizen*, Parker Filtration B.V., Netherlands* **(I–365)**

Fiber filters in water treatment - effect of fiber length and layering, *H. Liimatainen*, S. Kokko, J. Niinimäki, University of Oulu; S. Haavisto, VTT; M. Myllys, University of Jyväskylä, Finland* **(I–373)**

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Sludge liquor treatment with Kubota submerged membrane technology, *T. Wozniak*, Kubota Membrane Europe, Germany* **(II–595)**

Separate collection and treatment of hospital effluents for eliminating nutrients and micro-pollutants, *C. Mauer*, Pöyry GKW GmbH; J. Scholz, AV Aggerwasser GmbH; S. Baumgarten, RWTH Aachen University; T. Wozniak, WWS-consulting, Germany* **(II–604)**

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Design of filter bags by practice-oriented media tests including ageing, *P. Lohse*, FOS GmbH, Germany* **(II–322)**

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The influence of aging protocol on the filtration behavior of cleanable filter media, *J. Binnig*, J. Meyer, G. Kasper, University of Karlsruhe, Germany* **(II–336)**

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Arsenic removal from drinking water by coagulation/flocculation and solid/liquid phase separation, *D. Laky*, B. Laszlo, Budapest University of Technology, Hungary* **(I–393)**

Efficient liquid/solid separation by low energy microflotation in municipal and industrial wastewater treatment - An approach to the next generation flotation, *R. Damann*, O. Stark, A. Stein, Enviplan GmbH, Germany* **(I–402)**

L18 Vacuum Filtration and Tailings Processing 15:00-16:15

White pigment filtration on modified drum filters with roller discharge – significant performance increase by filter revamping, *T. Langeloh*, R. Bott, J. Hahn, Bokela GmbH, Germany* **(I–462)**

Investigation of cyanide adsorption natural zeolite surface from tailing dam water in Aghdareh Takab gold processing plant, *A. Khodadadi*, A. Samiee, Tarbiat Modaress University; A. Khodadadi Darban, Tehran University, Iran* **(I–470)**

G12 Filter Test Systems II 15:00-16:15

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Filter classification of oil and emulsion separators, *M. Sauer-Kunze*, GEA Delbag Lufttechnik GmbH, Germany* **(II–352)**

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Assessment of fluorescently labelled polyelectrolyte distribution in sludge flocs by confocal laser scanning microscopy, *D. Curvers*, H. Saveyn, B. Lucas, S. de Smed, L. Bonami, F. du Prez, P. Van Oostveldt, P. Van der Meeren, Ghent University, Belgium* **(I–419)**

Cost saving and intensification of WWTPs by chemical pre-treatment, *I. Licsko*, A. Szabo, Budapest University of Technology, Hungary* **(I–426)**

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Search for optimal pleat count based on filter quality, *C.-C. Chen*, T.-C. Hsiao, National Taiwan University; C.-W. Chen, S.-H. Huang, Institute of Occupational Safety and Health Taipei; C.-M. Chiang, National Cheng-Kung University, Taiwan* **(II–375)**

Advanced web-coating and laminating technology for filtration media, *R. Arnaboldi*, HIP-MITSU srl, Italy* **(II–376)**

L17 Particle Size Analysis for Solid-Liquid-Separation Processes 16:45-18:00

A new online particle counting cabinet, *C. Peuchot*, N. Petillon. I.F.T.S. Institute of Filtration and Separation, France* **(I–445)**

About calibration of light extinction automatic particle counters, *C. Peuchot*, N. Petillon. I.F.T.S. Institute of Filtration and Separation, France* **(I–456)**

Particle counting use in evaluation of filter performance, *A. Shalimashi*, IROST - Iranian Research Organisation for Science and Technology, Iran* **(I–462)**

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L2	**Cake Filtration Fundamentals** Chair: Hans Theliander	**15:00-16:15 h**
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L6	**Suspension Characterization by Sedimentation Analysis** Chair: Stephen Tarleton	**16:45-18:00 h**
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G4	**Electrostatic Precipitation** Chair: Hans-Joachim Schmid	**8:30-9:45 h**
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M2	**Poster Session M-I** Chair: Thomas A. Peters	**10:15-11:30 h**
G5	**Poster Session G-I** Chair: Eberhard Schmidt	**10:15-11:30 h**
L9	**Developments in Dynamic Cake Filtrations** Chair: Marja Oja	**13:15-14:30 h**
M3	**Simulation, Control, Design** Chair: Roger de Bruyne	**13:15-14:30 h**
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L10	**Developments in Pressure Filtration** Chair: Werner Stahl	**15:00-16:15 h**
M4	**Water Treatment and Reverse Osmosis** Chair: Siegfried Ripperger	**15:00-16:15 h**

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L11	**Hydrocyclones** Chair: Harald Anlauf	**16:45-18:00 h**
M5	**Gas Separation** Chair: Kuo-Lun Tung	**16:45-18:00 h**
G8	**Modelling and Simulation** Chair: Wilhelm Höflinger	**16:45-18:00 h**

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M6	**Separation of Complex Systems** Chair: Eugene Vorobiev	**8:30-9:45 h**
G9	**Industrial Gas Cleaning** Chair: Matthias Waldenmaier	**8:30-9:45 h**
L13	**Depth Filtration –** **Removal of Pollutions from Liquids** Chair: Martin Lehmann	**10:15-11:30 h**
M7	**Poster Session M-II** Chair: Thomas Peters	**10:15-11:30 h**
G10	**Poster Session G-II** Chair: Eberhard Schmidt	**10:15-11:30 h**
L14	**Depth Filtration –** **New Fibrous Media and Fiber Structuring** Chair: Karsten Keller	**13:15-14:30 h**
M8	**Membrane Bio Reactor** Chair: Jaroslav Pridal	**13:15-14:30 h**
G11	**Filter Test Systems I** Chair: Gernot Krammer	**13:15-14:30 h**
L15	**Depth Filtration and** **Microflotation for Water Treatment** Chair: Hermanes H. Kleizen	**15:00-16:15 h**
L18	**Vacuum Filtration and Tailings Processing** Chair: Thomas Langeloh	**15:00-16:15 h**
G12	**Filter Test Systems II** Chair: Matthias Waldenmaier	**15:00-16:15 h**
L16	**Flocculation/Coagulation of Waste Water Treatment** Chair: Urs Peuker	**16:45-18:00 h**
L17	**Particle Size Analysis for** **Solid-Liquid-Separation Processes** Chair: Harald Anlauf	**16:45-18:00 h**
G13	**New Filter Media** Chair: Jaroslav Pridal	**16:45-18:00 h**

ASSESSING THE PERFORMANCE OF COMBINATION PARTICULATE AND GASEOUS CONTAMINANT AIR FILTERS

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ABSTRACT

In recent years, several manufacturers have offered filters formed from media which are intended to remove both aerosols and gaseous contaminants. These “combo” filters have been supplied for both general-ventilation use and for vehicle cabin climate control systems. We analyze the performance of two filters of this type designed for vehicles. The analysis of performance is limited to their removal of volatile organic contaminants (VOCs) by activated carbons which have not been impregnated with additional chemicals. Inlet concentrations of VOCs were estimated from published values for the concentration of gaseous contaminants found in highway and street traffic. Published expressions for determining the retentivity of activated carbons, include the effects of contaminant type and concentration, filter flow rate and carbon bed characteristics were developed for much higher inlet concentrations than exist in even the most polluted street situations, and give impossible (negative-value) retentivities. We present an alternate analysis valid for VOC concentrations at the microgram-per-cubic-meter level. Retentivity and breakthrough time for benzene and acetaldehyde (typical VOCs) are calculated and compared to published test data on similar filters. The breakthrough times are short enough to raise questions regarding the usefulness of these filters with their very thin beds of activated carbon.

KEYWORDS

Activated Carbon, Adsorptive Materials, Adsorption, Air Filters, Automotive, Cabin Air, Dynamic Filtration, Fibrous Filter, Organic Contaminants, VOC

INTRODUCTION

Climate-control systems of automobile cabins are increasingly fitted with air filters made from thin sheets of media designed to remove both particulates (aerosols) and gaseous contaminants. In this case, the filter media are formed into V-pleats to lower media velocity, decrease pressure drop, and extend the life of the adsorption filter. Such “combo” filters are claimed to protect the health of passengers and to remove odors and irritants. Our examination of manufacturer’s literature does not show numerical test results for any specific gaseous contaminants. Instead, they describe these filters with phrases like “absorbs up to 100% of all pollen, dust particles and harmful substances”; ”absorbs toxic and foul-smelling gases such as ozone, nitrogen oxide, sulfur dioxide and hydrocarbons”; ”eliminates unpleasant odors”.

The sections which follow estimate the contaminant breakthrough time of typical automotive combo filters containing pleated multi-layer fibrous filter media and granular activated carbon. The contaminant concentrations assumed are at levels which have been measured for actual street and highway sites.

A defining characteristic of such filters is *retentivity*, the mass of contaminant stored in the adsorption medium up to the time when a chosen percentage of upstream contaminant concentration appears downstream of the filter. Another is *breakthrough time*, the time required to reach the downstream level used for the retentivity test. Our analysis predicts these two values, using reported gaseous contaminant concentrations met on motorways. We first tried analysis using well-verified theories describing the behavior of high-quality activated carbons. Those equations in them were established for contaminant levels met in gas-mask applications, which are ordinarily thousands of times higher than levels found on streets and highways. The equations predict impossible retentivity and breakthrough times (negative values) when concentration values like those seen on streets and highways are inserted.

The problem with low-level concentrations is that the adsorption isotherm is linearly related to concentration at low levels, not logarithmic, as appears in (1) - (4). After making this change, rational values for retentivity and breakthrough were obtained.

CONSTRUCTION OF COMBO FILTERS ANALYZED

Both filters analyzed were flat panels holding a pleated multi-layer web of non-woven synthetic organic fibers. A cross-section of the pleated materials for the two filters is shown in Figure 1. Between two of the non-woven layers of each filter there was a layer of granular activated carbon. The layers on either side of the carbon layer had openings small enough to prevent the migration or shake-out of the carbon granules.

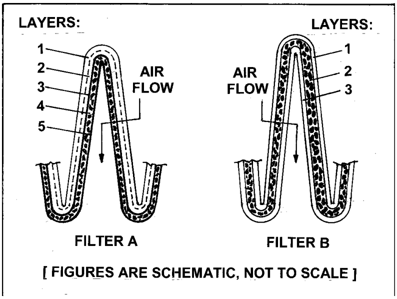

Figure 1 - Cross-Section of Media

In Filter A, layers 1,2,3, and 5 are nonwoven polymer fiber mats having thicknesses of ~ 0.3, 0.15, 0.1 and 0.1 mm; layer 4 is granular activated carbon having median diameter ~ 0.3 mm. In filter B, layers 1 and 3 are nonwoven polymer fiber mats ~0.28 mm thick, and layer 2 is granular activated carbon having median diameter ~ 0.4 mm.

OPERATING CONDITIONS FOR COMBO FILTERS IN VEHICLES

The filters are exposed to flow from the front of the vehicle, flow which is not intentionally pre-conditioned. The flow rates through the combo filter vary according to the level of heating or cooling selected by the vehicle operator. The media velocities listed, and hence calculated operating lives, are based on the assumption of an average air flow of 200 m^3/h, which is typical of automotive cabin heating and air conditioning systems at average conditions. Calculated lives are also given for air flows of 40 m^3/h, which might represent operation at minimum air conditioning or heating load.

Table 1 - Properties of Combo Filters Analyzed

Property	Filter	
	A	B
Face Area of Filter, m^2	0.024	0.025
Area of Media in Filter, m^2	0.1615	0.1925
Pleat Pitch (Crest-to-Crest Distance), mm	7.57	7.04
Pleat Depth, mm	26.6	27.7
Overall Thickness of Media, mm	1.15	1.25
Depth of Activated Carbon Layer, mm	0.5	0.7
Mass of Carbon per Unit of Media Area, g/m^2	361	244

HIGHWAY AND STREET GASEOUS CONTAMINANTS AND TYPICAL CONCENTRATIONS FOR THEM

Both type and concentration of contaminants vary by location, season, and hour of the day. World-wide studies have monitored gaseous contaminants, usually on the roofs of buildings, convenient locations for air sampling equipment. Less data is available from in or along streets and highways. The data from national air-pollution monitoring networks suggest what contaminants are serious toxins or irritants.

Table 2 - National Ambient Air Quality Standards for Criteria Pollutants

Pollutant	Primary Standard (μg/m^3)	Averaging Time
Carbon monoxide	40	1 hour
Lead	1.5	3 months
Nitrogen dioxide	100	1 year
Particulate matter(PM_{10})	150	24 hours
Particulate matter ($PM_{2.5}$)	65	24 hours
Ozone, O_3	167	8 hours
Sulfur oxides (assumed to be SO_2)	390	24 hour

The master list of “hazardous air pollutants” (5) identified by the U.S. Environmental Protection Agency (EPA) has 1161 entries whose concentrations and degree of hazard vary greatly. EPA has (6) divided this list into two categories: seven “criteria pollutants”, and 174 other “hazardous air pollutants” (HAPs), mostly volatile organic compounds (VOCs). The criteria pollutants and their acceptable concentrations are listed in Table 2 (from the actual table, we have selected the averaging times which have the highest concentration levels). From the 174 HAPs, EPA deemed 12 VOCs especially significant (6).

Estimates of the wide-area concentrations of these 12 are listed in Table 3; these may represent the *minimum* concentrations of these contaminants which would be met on streets or highways.
Measurements of concentration levels for VOCs on or near roadways are reported in several studies made for Australian governmental environmental protection agencies (7)-(10). Table 4 lists the average values of contaminant concentrations measured for some compounds deemed important by these authors.
The surprising thing about the data is that automobile drivers receive higher exposure to VOCs than bicyclists. The authors suggest that some pollutants reaching automobile passengers come *from the vehicle in which they are riding*.

Table 3 - Significant Toxic VOC Concentrations (EPA Estimates)

Pollutant	Background Concentration Estimate (μg/m^3)
Benzene	0.48
Carbon tetrachloride	0.88
Chloroform	0.083
Ethylene dibromide	0.0077
Ethylene dichloride	0.061
Formaldehyde	0.25
Hexachlorobenzene	0.000093
Mercury compounds	0.0015
Methylene chloride	0.15
Polychlorinated biphenyls	0.00038
Perchloroethylene	0.14
Trichloroethylene	0.081

Similar data from motorways in Copenhagen are given in Rank et al (11), and listed here in Table 4. They confirm the observation of Chertok (7) that passengers in cars have higher exposures than bicycle riders. Batterman et al (12) present similar data from Detroit motorways.

Table 4 - VOCs Street Concentrations: Averages for Bicycle/Automobile Riders

Pollutant	Automobile measurements μg/m^3	Bicycle measurements μg/m^3	Automobile measurements μg/m^3	Bicycle measurements μg/m^3
	Data from Chertok (7): Melbourne Motorways		**Data from Rank (11): Copenhagen Motorways**	
Benzene	39.8	22.5	14.4	5.1
Toluene	110.2	94.1	69	20
Ethylbenzene	19.4	12.0	67†	18†
Xylenes	87.8	53.6		
NO2	56.9	47.1	*	*
Hydrocarbons	*	*	215	58
Particles	*	*	75	44

* Not measured † Total of Ethylbenzene and Xylenes

THEORY OF PHYSICAL ADSORPTION OF GASEOUS CONTAMINANTS BY ACTIVATED CARBON AT HIGH CONCENTRATIONS (> 1 MILLIGRAM PER CUBIC METER)

Wood (1) presents a comparatively simple procedure for calculating efficiency and service life of a given carbon bed on a single given gaseous contaminant. It is based on well-proven theories and a very large number (1350) of actual tests of various carbons and adsorbates (= pollutant, contaminant) at various operating conditions related to gas-mask performance. It begins with the Wheeler equation as modified by Yoon and Nelson (2):

$$t_b = \left(\frac{W_e \cdot W}{C_o \cdot Q}\right) - \left(\frac{W_e \cdot \rho_B}{k_v \cdot C_o}\right) \cdot \ln\left(\frac{C_o - C_x}{C_x}\right) \qquad (1)$$

where:

t_b = breakthrough time, (min)
W = mass of activated carbon adsorbent (g)
ρ_B = bulk density of the carbon bed (g/cm^3)
Q = filter volumetric flow rate (cm^3/min)
C_o = inlet concentration of adsorbate (g/cm^3)
C_x = exit concentration of adsorbate (g/cm^3)
W_e = equilibrium adsorption capacity (retentivity) (g of adsorbate / g of carbon)
k_v = adsorption rate coefficient (min^{-1})

Unfortunately, for some values of these parameters, Equation (1) predicts zero or negative W_e. This is true for our combo filter forms, probably for any adsorbate, at reasonable cabin-filter operating conditions. For filter A, its measured characteristics and a reasonable set of operating conditions give these parameters:

d_P = mean diameter of carbon particles = ~0.06 cm
ρ_B = bulk density of the carbon bed = 0.48 g/cm^3

W = mass of carbon = 58.3 g
v_M = media velocity = 34.4 cm/s

Q = filter volumetric flow rate = 200 m^3/h = 3.33 x 10^6 cm^3/min

Wood takes the capacity W_e to be given by the Dubinin/Radushkevich (3) adsorption isotherm, equation (2):

$$W_e = W_0 \cdot \rho_L \cdot \exp\left[-\left(\frac{K \cdot R^2 \cdot T^2}{\beta^2}\right) \cdot \left(\ln \frac{p}{p_{sat}}\right)^2\right] \qquad (2)$$

where

W_o = carbon micropore volume (cm^3/g)	T = absolute temperature, (K)
K = carbon "structural constant"	β = "affinity coefficient" (dimensionless)
p = partial pressure of adsorbate corresponding to C_x, (Pa)	p_{sat} = saturated vapor pressure of adsorbate at temperature T (Pa)
ρ_L = liquid density of the adsorbate (g/cm^3)	R = ideal gas constant, 1.987 cal/(gmol K)

Lodewyckx and Vanzant (4) developed a correlation for the adsorption rate coefficient k_v :

$$k_v = 48 \cdot \beta^{0.33} \cdot v_M^{0.75} \cdot d_p^{-1.5} \quad (\text{min}^{-1}) \qquad (3)$$

where

d_p = mean diameter of carbon particles (cm); v_M = media velocity (cm/s)

For benzene, β = 1.01, hence k_v = 46544, which inserted in Equation (1) gives t_b in minutes:

$$t_b = \left(\frac{W_e}{C_0}\right) \cdot \left[\frac{58.3}{3.33 \cdot 10^6} - 2.9444 \cdot \frac{0.48}{46544}\right]$$

The term in brackets is [$17.5x10^{-6}$ -$30.4x10^{-6}$], which is less than zero. The value for k_v is if anything, high, and a lower value would give an even more negative t_b.

Earlier studies verified Eqs. (1)-(3) by testing at mg/m^3 concentration levels. All three probably have different forms at μg/m^3 levels. Ramanathan et al (13) tested a high-quality coconut shell activated carbon for adsorption of three VOCs at concentrations from 100 ppb to 183 ppb. Their results are given in Table 5. These are static adsorption isotherm measurements, used to determine W_e.

The benzene data fit a reasonably straight line passing through (0,0), hence it is reasonable to suppose that W_e is proportional to the inlet concentration at these low concentrations, or:

$$W_e = K_2 \cdot C_0 \quad (4)$$

Fits to the three data sets of Table 5 give the following K_2 coefficients for these three VOCs: for benzene, W_e (μg/g) = 0.1012 C_0; for acetaldehyde, 0.1770 C_0; for trichloroethane, 0.0793 C_0 . Here C_0 is in μg/m^3.

Table 5. Low-Concentration Retentivity for a Coconut-Shell Activated Carbon

Adsorbate	C_o (ppb)	C_o (μg/m^3)	W_e (10^{-7} mol per g of carbon)	W_e (μg per g of carbon)
Acetaldehyde	119	218	10.0	44.05
	153	280	10.0	44.05
Benzene	101	328	4.30	33.59
	119	387	5.60	43.74
	176	572	6.33	49.44
1,1,1 Trichloro-Benzene	115	638	2.04	27.21
	183	1016	1.91	25.48

PREDICTED GASEOUS CONTAMINANT PERFORMANCE OF COMBO FILTERS STUDIED

For these very low adsorbate mass loadings in the carbon, it is reasonable to assume that essentially all of the adsorbate reaching the carbon bed is adsorbed, hence:

$$t_b = \frac{W_e \cdot W}{Q \cdot C_0} \text{ (min)} \qquad (5)$$

where W_e is given by Equation (4), not Equation (2). Table 6 shows the breakthrough time calculation for three VOCs for filter A. Filter B has slightly less carbon (47.0 g) hence would show break times 81% of the values in Table 6.

Table 6 - Breakthrough Time for Filter *A* At 50 µg/m³ and 40 and 200 m³/h Flow

Constant Factors for Equation 4 and 5: W = 58.3 g; C_o = 50 µg/m³ = 50 x 10^{-12} g/cm³				
Adsorbate	40 m³/h (0.666x10^6 cm³/min)		200 m³/h (3.33x10^6 cm³/min)	
	W_e µg/g	t_b min	W_e µg/g	t_b min
Acetaldehyde	8.85	15.6	8.85	3.10
Benzene	5.06	8.9	5.06	1.77
1,1,1 Trichloroethane	3.97	7.0	3.97	1.39

MEASURED PERFORMANCE OF COMBO FILTERS REPORTED BY OTHERS

We found only two serious reports of test data for combo filters, Rudell et al (14) and Lee et al (15). Rudell exposed 32 volunteers to diluted diesel exhaust in a laboratory facility. Filters were evaluated for their impact on physiological effects and odor perception by the subjects. Some upstream gaseous contaminant concentrations were monitored. Acetaldehyde concentration, for example, was approximately 30 µg/m³. Downstream concentrations showed no reduction for aldehydes, but efficiencies of 67% to 87% on “total aliphatics” and “total aromatics”. Eye, nose and throat irritation, headaches and odors were significantly reduced by one particulate-carbon filter combination, but the other three filters gave ambiguous results. Lee et al (15) report the performance of four filters identified as “cabin filters”, with granular activated carbon bed thicknesses of 1.0 to 2.2 mm. The only contaminant tested was ozone, at 250 µg/m³. Their Figure 11 shows that a filter with 2.2 mm bed thickness had initial ozone removal of 98%, dropping to 20% at 80 minutes continuous exposure (50% RH, 1.52 m/s bed velocity).

CONCLUSIONS

Calculation of activated carbon retentivity and breakthrough time for thin beds at adsorbate concentrations < 1 mg/m³ is impossible using the Dubinin/Radushkevich logarithmic isotherm. Experiment shows that the isotherm is linear for such low concentrations. Calculation then shows that the thin carbon beds in “combo” filters have breakthrough times for VOCs so short that the filters are essentially useless. Isotherm data for VOCs at pressures corresponding to concentrations < 1 mg/m³ is almost non-existant. This data for significant pollutants is needed if meaningful evaluation of vehicle cabin filter performance on toxic VOCs is to occur.

ACKNOWLEDGEMENTS
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