TRIPP BULLETIN
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TRANSPORTATION RESEARCH & INJURY PREVENTION PROGRAMME
INDIAN INSTITUTE OF TECHNOLOGY DELHI

Publications

Advani,M. and Tiwari,G. (2006) **Does High Capacity Mean High Demand?** *3rd Interantional Conference on Future Urban Transport, 2-5 April 2006, Volvo Research Foundations, Goteborg.*

Anand,A. and Tiwari G. (2006) **A Gendered Perspective of the Shelter- Transport-Livelihood link: The Case of Poor Women in Delhi.** *Transport Reviews 26, 63-80.*

Balaraman,K., Mukherjee,S., Chawla,A., and Malhotra, R. (2006) **Inverse Finite Element Characterization of Soft Tissues Using Impact Experiments and Taguchi Methods**. *In SAE, Warren, USA.*

Gawade,T.R., Mukherjee,S., and Mohan,D. (2005) **Six-degree-of-freedom: Three-wheeled-vehicle Model Validation**. *Proceedings of the I MECH E Part D Journal of Automobile Engineering 219,487-498.*

Kumar,A., Mathur,N.N., Varghese,M., Mohan,D., Singh,J.K., and Mahajan,P. (2005) **Effect of Tractor Driving on Hearing Loss in Farmers in India**. *American Journal of Industrial Medicine 47, 341-348.*

Mohan D. (2005) **Safety and Sustainable Urban Transport**. In *Urban Transport Development: A Complex Issue (Edited by Jonson,G. and Tengstrom,E.) Pp.279-300. Springer-Verlag, Berlin.*

Mohan,D., Roy,A.K., Kale,S.R., and Chakravarty,S.N. (2006) **Use of Epidemiology In The Public Space: Reconstruction of A Train Fire in India**. *African Safety Promotion: A Journal Of Injury and Violence Prevention 4,140-149.*

Mohan,D. (2005) **Traffic Safety (Leonard J. Evans): Review**. *BMJ 330, 367.*

Mohan,D. (2005) **Evidence-based Interventions for Road Traffic Injuries in South Asia**. *Journal of The College of Physicians and Surgeons Pakistan 14, 746-747.*

Mohan,D. (2006) **Road Traffic Injuries and Fatalities in India - A Modern Epidemic**. *Indian J Med Res 123, 1-4.*

Mukherjee,S., Chawla,A., Nayak,A., and Mohan,D. (2005) **Rollover Crash Analysis of the RTV Using MADYMO**. In *Proceedings Symposium on International Automotive Technology, SIAT2005-SAE Conference Pp. 701-709.*

Seedat,M., MacKenzie,S., and Mohan,D. (2006) **The Phenomenology of Being A Female Pedestrian in an African and an Asian City: A Qualitative Investigation**. *Transportation Research Part F: Traffic Psychology and Behaviour 9, 139-153.*

Soni,A., Chawla,A., and Mukherjee,S. (2006) **Effect of Active Muscle Forces on the Response of Knee Joint at Low Speed Lateral Impacts**. *SAE 2006 World Congress & Exhibition, Detroit.*

Tiwari,G. (2006) **Path to Achieving A Good Transport System: Lessons Learnt From Bogota to Delhi**. *3rd International Conference on Future Urban Transport, 2-5 April 2006, Volvo Research Foundations, Gothenburg.*

In proceedings 8th World Conference on Injury Prevention and Safety Promotion, 2-5 April 2006, Durban:

Anand,A. and Tiwari,G. (2006) **Unsafe Access: Vulnerability of Public Transit Users During Access Trips**.

Gandhi,S., Tiwari,G., and De Wit,R. (2006) **Planning For Safe Commuter Access on "Bus Rapid Transit" Corridors in Delhi.**

Gupta,B., Kumar,A., and Varghese,M. (2006) **Impact Assessment of Child-To-Child First Aid Training in Senior Secondary Schools of North-East Delhi, India.**

Mahajan,P. (2006) **Finite Element Analysis of Helmet Impact Under Dynamic Loading.**

Sanghi,S., Mahajan,P., Pinnoji,P., Jain,S., and Yadav, P. (2006) **Analysis of Air Flow Inside the Helmet.**

Research & Consultancy Projects

Sustainable Urban Transport in Less Motorised Countries Research and Training. *Volvo Research & Educational Foundations. D. Mohan, G. Tiwari, A. Chawla, S. Mukherjee, S.R. Kale, P. Mahajan, S. Sanghi, R. Ravi, Dunu Roy and M. Varghese.*

Technology Development for Collecting Bone and Tissue Properties and Development of Human Body FE Model-Phase II & III. *Japan Automobile Research Institute. A. Chawla, S. Mukherjee and D. Mohan.*

Development of FE Models for Human Body Parts for Impact Simulation. *Miinistry of Human Resource Development. A. Chawla and S. Mukherjee.*

Obtaining Low-Speed Impact Properties of Soft Tissues. *Miinistry of Human Resource Development. A. Chawla and S. Mukherjee*

Implementation of High Capacity Bus System Corridor. *Transport Department, Government of Delhi. G. Tiwari and D. Mohan.*

India Liveable Communities Initiative. *Institute for Transportation and Development Policy (ITDP), USA. G. Tiwari and D. Mohan.*

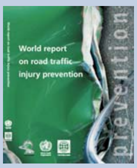
Development of a Training Manual for Road Traffic Injury Prevention. *World Health Organization. D. Mohan and G. Tiwari.*

Airport traffic Circulation in Northern Region. *Airport Authority of India. G. Tiwari and D. Mohan.*

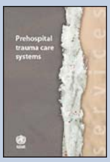
Low Cost Mobility Initiative. *I-CE, The Netherlands. G. Tiwari and D. Mohan.*

Designing the BRT System on Hadapsar Road(Pune), *The Municipal Corporation of the City of Pune. G. Tiwari and D. Mohan.*

Planning & Re-development of Spaces Around the Various Terminals at Delhi Airiport. *Pradeep Sachdeva Design Associates & GMR Infrastructure Ltd. G. Tiwari and D. Mohan.*



World Report on Road Traffic Injury Prevention
Margie P., Scurfield R., Sleet D., Mohan D., Hyder A., Jarawan E., Mathers C.
World Health Organization, Geneva
http://www.who.int/world-health-day/2004/infomaterials/world_report/en/



Prehospital Trauma Care Systems
Sasser S., Varghese M., Kellerman A., and Lormand J.D.
World Health Organization, Geneva
http://whqlibdoc.who.int/publications/2005/924159294X.pdf

The Saga of Rickshaw: Identity, Struggle and Claims
A study by Lokayan 2004. Editor: Rajendra Ravi

The **Transportation Research and Injury Prevention Programme (TRIPP)** at the Indian Institute of Technology Delhi, is an interdisciplinary programme focussing on the reduction of adverse health effects of road transport. TRIPP attempts to integrate all issues concerned with transportation in order to promote safety, cleaner air, and energy conservation. Faculty members are involved in planning safer urban and inter-city transportation systems, and developing designs for vehicles, safety equipment and infrastructure for the future. Activities include applied research projects, special courses and workshops, and supervision of student projects at postgraduate and undergraduate levels. Projects are done in collaboration with associated departments and centres at IIT Delhi, government departments, industry and international agencies.

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Air Flow Through a Bus with Open Windows

S.R. Kale

S.R. Kale is a professor in the Department of Mechanical Engineering at the Indian Institute of Technology Delhi. His current research interests include the aerodynamics of the ceiling fan, evaporative cooling by water sprays, flows of particle laden air and coal and oil combustion.

You generally work on complex aerodynamic projects; what led you to this particular problem?

In the first place, I would like to mention that this too is a problem in aerodynamics like any other. Now, for the second part of the question. In such matters, several factors combine to make up the reason why one enters a certain field of enquiry. Let us see what some of them are. Discomfort as a passenger in the bus prompted me to think of the problem of air circulation. The aerodynamics of vehicles (cars, trains, trucks and buses) is a well researched field but all this work concentrated on vehicles with closed windows; focussing on making the outside shape smooth and aerodynamic. The comfort factors inside relied on heating/air-conditioning. These studies did not pay much attention to vehicles with high occupancy which itself can affect passenger comfort levels. Buses are the common means of mass transport in India and other parts of the world. They are the backbone of any sustainable mass transport system. By improving the aerodynamics of the bus, one reduces drag and increases fuel efficiency. On per passenger per kilometer basis, the fuel economy is better and emissions are lower than either the automobile or motorized two-wheelers. A continuous row of windows is provided on both sides of the bus; then there are the doors. While in motion, the passenger door(s) may or may not be fully open. Individual passengers adjust the window opening to suit their needs. Some buses have one or two adjustable openings on the roof.

Plying on highways and dirt roads, buses touch remote locations. In urban areas, they are a major mode of travel to and from work. Inter-city buses cater to a large number of passengers over short and medium distances. Almost all these buses whether owned/operated by private or public enterprises, are not air conditioned, primarily to keep fares low. Consequently, the windows and doors are kept open so that air circulation induced by the motion of the bus will result in better comfort.

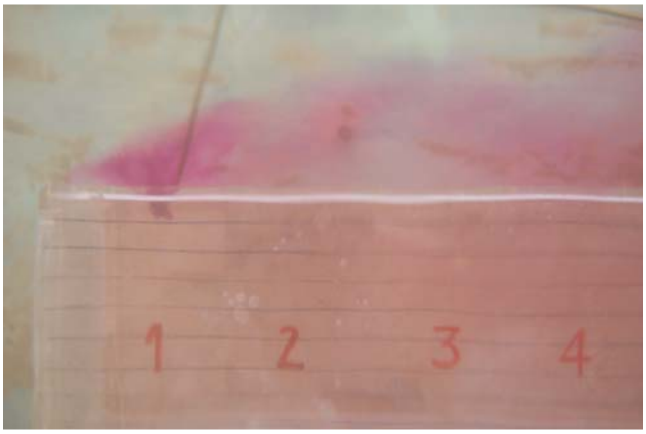
Although viewed as essential, bus services and buses are generally looked down upon for a variety of reasons. Their upkeep aside, passenger amenities, such as seats and standing space, are inadequate and uncomfortable; they are noisy and vibrate. The climate of large regions in India, as also elsewhere in the world, is characterized by high ambient temperatures as well as high humidity for most months in a year. This aspect coupled with high passenger occupancy, also termed packing density, results in poor comfort levels inside the bus as quantified by air temperature, humidity and velocity. Window seats are at a premium and some passengers prefer traveling on the footboard or standing in the open door. This aspect is amongst the major contributors to the perception of bus travel as uncomfortable.

The inside comfort can be improved with air conditioning which requires closing the windows; this is the basis of on-road air conditioned buses and here the air conditioning equipment is roof mounted. The capital cost increases and so does the running cost. Because of this aspect, and the need to keep fares low, it is unlikely that there will be a large scale conversion to air conditioned buses in the near or long term. Besides, such conversion would increase fuel consumption and add to vehicle emissions. From a health perspective too, traveling in air conditioned buses for short durations is not advisable. Thus, bus travel which is the backbone of public transport in India will continue with non-air conditioned buses. It thus becomes imperative to improve comfort levels while relying on motion-generated circulation, or alternately from fans or blowers mounted inside the bus. The efficacy of roof openings, provided for this very purpose, has not been established and experience suggests that the effect is marginal at best. Such design interventions are traceable to bus body builders who have little or no knowledge about vehicle aerodynamics.

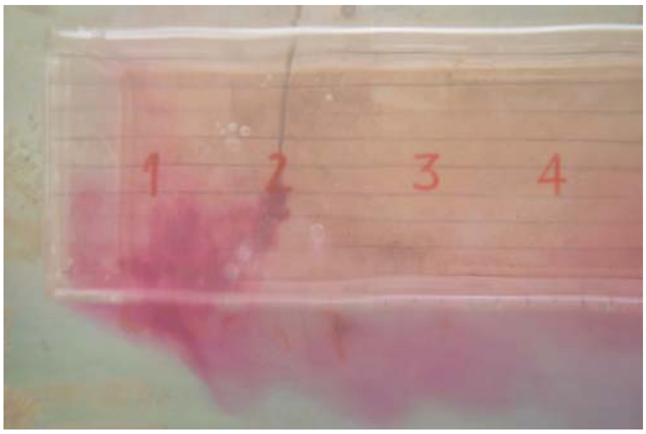
A review of the aerodynamics of trucks, buses and trains is given in McCallen et al, (2002). This review covers advances on important fluid mechanics aspects, such as, detached eddy simulation, as well as application specific studies. Both experimental and numerical simulations are presented. In all these studies, the vehicle windows are closed so that the external shape resembles a smooth closed body; there are no connections between the air inside and outside the vehicle.

The aerodynamics of trains, particularly high speed trains, has been extensively studied; these studies, too, consider the passenger compartments to have closed windows and doors so that the exterior presents a smooth surface to airflow over it. The condition of coaches with open windows has not been studied. Findings from studies on closed passenger compartments with smooth exterior, experimental or computational, cannot be extended to the open window vehicle configuration on which there have been no specific studies. When traveling by bus in India I was struck by the extreme discomfort caused by the lack of fresh air in spite of all the windows being open; this was further compounded by the high packing density and heat of over crowding. Accordingly I decided to enquire into the problem.

Low floor urban bus



Air flow - bus with open window visualization at first window



Air flow - bus with open window visualization inside bus front

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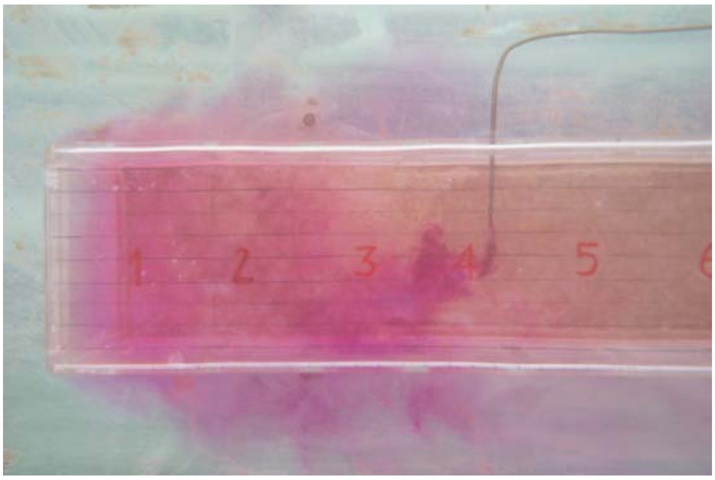
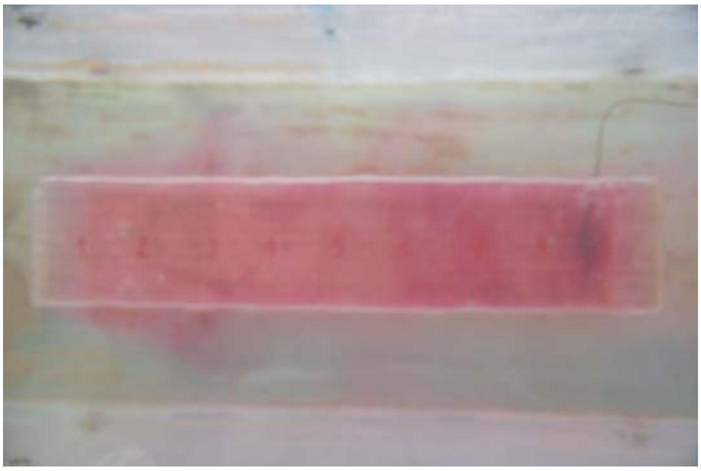
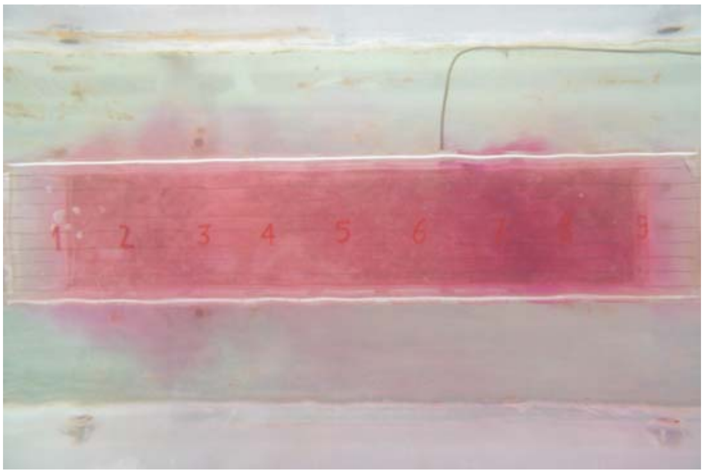


Air flow - bus with open window visualization inside bus middle



Air flow - bus with open window visualization inside bus rear



Air flow - bus with open window visualization at side center

Why is the explanation for this simplesounding problem so complex?

When an object moves through a medium like air or water, it generally presents a solid, smooth surface. Look at birds, fish, aeroplanes, etc. There is no break or gap in their bodies where the air or water can enter. If this happened, as in the case of buses with open windows, the geometry would become three dimensional and the complexity would increase; this is further compounded with the introduction of several features (seats, people, etc).

What were your first steps and what did you find?

The practical solution to increasing our ventilation is not as simple as it seems. We looked at local trains (EMU or Electric Multiple Units) as they are commonly known in India. We also studied all the available research papers and literature on the subject and found to our surprise that this aspect of the problem had been completely neglected. We were spurred on by this fact to pursue the problem further and identify the design changes to improve air circulations and enhance passenger comfort, reduce drag reduction and enhance fuel economy.

Flow visualization experiments were performed in a water channel, and since the Reynolds number was about an order of magnitude smaller than the real condition, visualization was performed on a real bus itself. For water channel visualization a model was designed and to facilitate comparison with simulations, the same model was used there also. The geometry was kept realistic as well as simple to enable clear conclusions. Flow visualization was performed by injecting colored water that was produced by mixing potassium permanganate or green/red ink in water. Flow visualization with smoke was performed in a moving bus on a straight, level road at a speed of 20 km.h-1. The bus had no passengers, the doors were closed and windows adjusted to produce nearly symmetric openings on both sides. The tests were performed when wind was negligible. Smoke patterns from a lighted dhoop were recorded on still and video cameras. Also, wool tufts stuck to a wire were placed at different locations in the windows to identify direction of airflow. Air flow through the roof ventilators that are commonly provided on a bus was also studied.

Did your findings surprise you?

We were quite astonished by our findings. The air does not enter the bus in any appereciable quantity through the first few windows on either side. Air rushes in through the last windows on both sides and moves internally towards the front of the bus, only to exit by the first two windows on both sides. We had just not imagined that the air circulation in a morving bus would assume this strange pattern; what was surprising was not only the entry point in the rear but its flow in a direction contrary to the movement of the bus. Armed with this information, even simple modifications with fans and water evaporative systems could enhance comfort levels for bus passengers.

What implication does this research have for bus design?

This research is particularly relevant to India and other large parts of the world that have hot, humid climates. In such developing countries the need for public transport is paramount. And the most effective, adaptable, economical, safe and clean means of mass transit is the bus. Our research helps us get the best airflow to enhance passenger comfort with the minimal and least expensive interventions. This can be further optimized with add on features like blowers/fans and evaporative water cooling systems. The other objective of this research is to reduce aerodynamic drag and increase fuel efficiency. The knowledge gained from this experiment can be advantageously applied to air conditioned buses to optimize air-conditioning efficiency. Further extension of this research would improve ventilation and passenger comfort in EMUs as in 3-tier sleeper coaches in trains. By adding combustion models to these flows, fire safety can be enhanced.

What work are you engaged in at present, in addition to the air circulation work?

We are looking at the aerodynamics of the ceiling fan; evaporative cooling by water sprays; flows of particle laden air; and, coal and oil combustion.

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"PRINCIPAL Voices" in CNN FORTUNE TIME

Geetam Tiwari

Principal Voices gathers together a series of the world's foremost thinkers in their respective areas. For 2006 this includes environment, urbanization, collaborative corporation and economic development. Among their ranks are university professors, business leaders and charity pioneers, not to mention Nobel Prize winners. Dr. Geetam Tiwari who teaches at IIT Delhi has been invited to submit a white paper on Urban Transport Planning and take part in round table events around the world in the course of 2006.

"Despite a high share of walking trips and trips by non-motorized means, transport infrastructure investment continues to ignore inclusion of facilities for these modes, while public-transport discussions center largely on capital-intensive systems like the metro, the argument given for introducing metro systems is that they serve the high-density demands of the city's corridors. Indian cities have high-density developments in the form of urban slums, but even a subsidized metro system is too expensive for slum dwellers. Any rail-based system requires a high-density population living along the corridor who can afford the price of that system. This is not the case in most Indian cities. Current urbanization patterns present a unique opportunity to build an inclusive city that caters to all segments of society. The challenge is to move away from policies and development plans which ignore the existence of the informal sector in housing, transport and livelihood opportunities." *www.principalvoices.com*

News

Severity of head-on crashes on two-lane rural highways

Head-on crashes on these roads account for less than 5% of the crashes, but they are responsible for almost half of all fatalities. Two in three fatal head-on crashes occurred on straight segments and 67% of these happened on dry pavement. There is a clear trend towards higher speed limits leading to a higher percentage of crashes becoming fatal or having incapacitating injuries. There is also a clear trend - if one keeps speeds constant and AADT within a certain range - that wider shoulders give higher crash severities. Also, for higher-speed roads, more travel lanes (than two) increase crash severity. In summary, there seems to be two major reasons why people get across the centerline and have head-on collisions: (a) people are going too fast for the roadway conditions; or (b) people are inattentive and get across the centerline more or less without noticing it. The latter category of crashes could probably be reduced if centerline rumble-strips were installed. Furthermore, today's speed limits should be better enforced since a high percentage of serious crashes involve illegal speeding. This should be combined with lowered speed limits for targeted high-crash segments.

Segment characteristics and severity of head-on crashes on two-lane rural highways in maine. Per Garder, Accident Analysis & Prevention, Vol. 38, No. 4, pp 652-661.

Roundabout?

When traffic engineers plan the roads that eventually will accommodate traffic in new developments like this, the plans usually involve interesections with stop signs or signal lights. But the barren site of a future intersection might be an opportunity to consider another option for traffic management, the modern roundabout. These have been built by the tens of thousands worldwide. The main benefits have been to improve traffic flow and reduce injury crashes by as much as 75 percent compared with intersections controlled by stop lights or signs.

Institute researchers studied 10 intersections where roundabouts could have been constructed but weren't. Instead local officials either outfitted the new intersections with traffic signals or retained the signal lights at intersections that were undergoing major modifications, the researchers measured traffic volumes, monitored the number of crashes that occurred, and estimated vehicle delays and fuel consumption at the intersections with the signals. Results were compared with estimates of what could have been expected with roundabouts instead.

A key finding is that vehicle delays at the 10 intersections could have been reduced by 62-74 percent, saving 325000 hours of motorists' time annually. Fuiel consumption would have gone down by about 235,000 gallons per year, and there would have been commensurate reductions in vehicle emissions. The safety benefits also are considerable. Previous research indicates that roundabouts reduce crashes by 37 percent overall --injury crashes by 75 percent-- compared with intersections that have signals. Applying these risk reductions to 5 of the 10 intersetions for which crash data were available, researchers estimated there would have been 62 fewer crashes over 5 years. There would have been 41 fewer injury crashes.

"If only 10 percent of the 250000 intersections with signals in the United States were modified as roundabouts, the national safety and fuel saving benefits would be enormous," Retting points out, "and you can reap these benefits without as many logistical challenges if you 'think roundabout' from the very beginning."

Previous before-and-after surveys have revealed similar turnarounds in public opinion (see *Status Report, July 28, 2001; on the web at www.iihs.org*). This is because many motorists find out, through their own experience, that vehicles generally flow more smoothly through roundabouts than through intersections controlled by traffic signals. Delays are reduced. In many cases there's no need to stop at a roundabout, just slow down.

Roundabout?, Status Report, Vol 40 No. 9, Nov. 119, 2005

Future Events

The Australian Injury Prevention Network (AIPN) and the Capacity Building Collaboration in Injury, Trauma and Rehabilitation (ITR) are pleased to invite you to attend the AIPN 8th Australian Injury Prevention Conference to be held in Sydney, 27-29 September 2006. The conference theme of "Working Together" emphasises the increasing need for researchers and injury prevention practitioners to embrace a broad multi-disciplinary approach; an approach that is across a variety of settings, injury issues and population age groups.
http://www.aipn.com.au/AIPNconf2006/home.htm

The 5th Better Air Quality (BAQ) workshop will be held on 13-15 September 2006 in the historic city of Yogyakarta in Central Java, Indonesia. The theme of BAQ 2006 is called a "Celebration of Efforts" to highlight the success stories that Asian countries, cities and communities have achieved over the last years in addressing air pollution while at the same time highlighting the efforts that are still ahead in improving air quality in Asia.
http://www.cleanairnet.org/baq2006/1757/channel.html

IRCOBI

The 2006 International IRCOBI Conference will be held in Madrid, Spain from September 20-22, 2006
http://www.ircobi.org/interface.html

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