Four Discussion Pieces on Setting Air Quality Guidelines*

HEI Annual Conference, San Francisco
April 9, 2006

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*Based on discussion pieces prepared for the WHO Air Quality Guidelines Expert Committee Meeting, October 2005, Bonn

#1 How Can AQGs be Specified for a Pollutant that has No Threshold for Health Effects? The Euro-x model

Perhaps the thorniest strategic issue to be addressed by a group charged with developing global air quality guidelines (AQGs) is how to deal with pollutants for which current scientific evidence does not support an effects threshold above zero or some other very low exposure concentration. Here I will discuss this issue with regard to small particles (PM), but similar considerations and difficulties apply to other pollutants as well.

Unlike the 1987 version, the last version of the WHO Global AQGs (1999) did not specify actual PM guidelines, but presented the best estimate of the exposure-response relationship in the form of a table showing the relationship of percent increases in mortality with exposure concentrations. It is widely perceived that this approach was not well received by users of the document, however, and led to little application of the guidelines by policy makers around the world. The question then is what else can be done?

The principal argument for stopping short of recommending numerical AQGs when there is no threshold seems to be that the choice would amount to making a cost-benefit (or risk-benefit) trade-off for the world's populations, something the committee is not constituted in expertise or representativeness to do. Who are we, it is argued, to decide what an acceptable level of pollution (risk) would be for the vast variety of circumstances in the world where the AQG might be applied? This can only be done fairly at the local level, preferably with all relevant stakeholders involved in the decision.

There are at least two classes of considerations, however, that argue against this approach; the first technical:

- In reality, such a risk-benefit tradeoff is inherent in every AQG ever promulgated, whether for pollutants with thresholds or not. Consider three reasons;

    - Choosing a level below the threshold is not somehow empty of such a trade-off: why there, why not above the threshold if the local risk-benefit calculus prefers it? Would we then need to provide an exposure-response table for all pollutants?
    - Thresholds, if they exist, are certainly not sharp. An AQG based on a threshold will not protect every sensitive group or every group exposed, since there are significantly broad and usually poorly known distributions of both sensitivities and exposures for any pollutant. To be sure to protect everyone would probably require near zero AQGs for most pollutants. The (usually implicit) choice of what fraction to protect is again a risk-benefit judgment.
    - The standard choice of 5% confidence intervals amounts to a risk-benefit tradeoff, albeit one protected by mountains of tradition and burial deep in the details.

The second, practical, argument is that by failing to choose numerical guidelines, we fail in our mission to the policy community. It needs numbers from WHO as benchmarks. Publishing a WHO slope does not help (or hinder) those countries with their own capability to develop standards, for they will review the scientific evidence on their own and make their own decisions. For other countries' policymakers, however, accepting the slope from WHO, from their standpoint, may lead them to become embroiled in local politics and debate. The result is that countries have a strong incentive to find reasons not to use WHO guidelines, for example by claiming that the population does not respond in the same way as indicated in the WHO slope.

Dealing with important health-damaging environmental stresses without thresholds is not unique to air pollution committees. The International Commission for Radiological Protection (ICRP) and the US National Council on Radiation Protection and Measurement (NCRP) are venerable organizations that regularly convene groups of scientific experts to review the evidence on health effects from radiation and issue guidelines for use by policy makers and regulatory bodies. They do this recognizing that for many of the radiation types they address there are not identifiable thresholds. Even though they do not attempt to include representatives from all possible stakeholder groups, their general professionalism, impartiality, prestige, and authority are such that nearly all governments in the world adopt the levels recommended. See http://www.icrp.org/

ICRP/NCRP's long and mostly successful history of establishing scientifically justifiable as well as workable and acceptable guidelines for ionizing radiation (as well as performing many other tasks related to radiation) is tribute to their structure, science, and management and the individuals associated with them. That radiation has been the focus of much public fear and the institutions involved with it the focus of so much mistrust makes the achievements of these organizations even more impressive. Although dealing with significant health risks stemming from large industries, however, compared to particle pollution, the impacts are small and the extent of the economy potentially affected by controls is relatively minor. Millions of people die prematurely each year from particle exposures around the world and the energy-using activities that are mostly responsible probably make up some 20% of the global economy. Thus, although setting PM guidelines may be relatively free of pressures due to public fear, the trade-offs inherent in them are arguably far more important for health and the economy. These facts alone should bring pause to any committee's ambitions to choose numerical levels in the absence of an identifiable threshold of "no-effect."

A possible way out

In the absence of resource constraints due to competing needs in society, there might be little compunction in establishing the lowest conceivable exposure level as the AQG, with multiple safety margins to take account differential population vulnerabilities. It is well recognized, however, that this is not useful or appropriate. The extremely stringent occupational and other standards established in the old USSR, for example, were examples of such an approach, laudable in a way, but wildly unachievable and widely ignored and thus having little impact to protect health.

There are, however, serious competing demands for resources to protect environmental health and for other priorities as well as heavy costs for meeting tight pollution control requirements in the richest country, and even more so in poor countries. In general, of course, the resources available to be spent are a strong inverse function of national income, although there are other factors as well. Thus, the approach of simply establishing an AQG that would be similar to those applied in the richest countries would risk the USSR effect, i.e. result in some hand wringing but little actual impact in much of the world. On the other hand, to choose the laxest of AQGs in the world, i.e., the lowest common denominator, is not an acceptable solution either as it has no potential to improve protection.

A way out of this dilemma is to recognize that the choice of an AQG is not something set for all eternity, but something revisited over the years in all countries. What is important is setting into motion a process whereby, over time, a country comes to protect its residents as much as it can, given it resources at each point in time. This is quite compatible with history for in most countries with standards that go back many decades there has been a progression over time to, usually, tighter standards. These have been driven by better knowledge but also by more resources being put toward protection.

An instructive example of this approach in a closely linked arena is auto emission standards in Europe, the Euro-1, Euro-2, etc. series, each tighter than the one before with Euro-5 coming into force in Europe in 2010 and preliminary discussions on Euro-6 being held. (See Table) Europe establishes them for regulating its auto industry and cleaning its air over time as technology develops. By force of example, a sound technical basis, and the size of the European auto market, the Euro-x standards have come to become a set of benchmarks across the world amounting, if you will, to a ladder or slope of successive risk-cost tradeoffs extending upwards in time, i.e., toward higher protection but higher cost. By allowing for industry (auto and fuel) participation in setting the decisions and incorporating firm forward schedules, tighter standards are able to be promulgated earlier than otherwise and still be acceptable to industry. Uncertainty, a bane to industry and a worry for the public, is reduced, and a clear path to a cleaner future is illuminated.

What we might do, therefore, is to establish a set of PM benchmarks labeled, perhaps, the WHO-1, WHO-2 … PM AQGs. These could be set in such a way as to encourage significant, but not unattainable, increments of protection from step to step, but start near the lowest common denominator and extend up to near the current tightest in the world. Countries therefore, could enter the sequence at any point, but with a plan over time to move up the ladder to more stringent levels. The planned change from one to the next would come at intervals related to local needs, resources, and politics. Governments, industries, and the citizenry could then see what path they were on over time, the costs that would be implied, and the residual risks that might be left. As with the Euro-x standards, governments would naturally feel some pressure to have their countries move up the ladder in an expeditious manner.

Of course, each WHO-x level might deal with more than one size range of PM and perhaps eventually with different chemical types. A more ambitious approach would be to follow the Euro-x model even more closely, and establish AQGs for a suite of the most important airborne pollutants for each WHO-x level (NOx, CO, etc.). Needless to say, to do so well, would require substantial new analytic work and thinking about the appropriate levels and linkages at each step. Although by no means trivial, the effort to do so for auto emission standards (Euro-x) was easier in this regard because each level corresponds to a particular combination of control efforts in fuel, engine, and exhaust. Although this would be partly the case for WHO-x levels as well, the total number and type of control activities are much more extensive and locally specific. This would make it more difficult to link AQGs for different pollutants into one WHO-x level.

Resource constraints in developing countries are not expressed just in funds available in government and industry to implement new standards, but in the entire apparatus of legal, technical, and other institutions; trained technical and professional staff; demographic, health, economic, geographic and other data collection and processing systems; reliable power supplies, and so on. These build up slowly and at different rates, hampering the implementation of new standards. Thus, part of the WHO-x series of AQGs will need to be recommendations on some of these other issues, particularly with regard to monitoring technology, siting and sampling protocols, quality assurance, and so on.

Recommendation;

The global Air Quality Guidelines should include tiered values for PM and potentially other pollutants providing incentives over time for countries to move to more protective levels as their circumstances allow.

Euro-x Auto Emissions Standards
http://www.euractiv.com/Article?tcmuri=tcm:29-133325-16&type=LinksDossier

Emissions Standard	Particulate matters (PM) (mg/km)	-	Oxides of nitrogen (NOx) (g/km)	-	**Hydrocarbons (HC) (g/km)**	-	Carbon monoxide (CO)(g/km)	-
-	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel	Petrol
Euro 2 (1996)	80-100	-	-	-	-	-	0.7/0.9	0.5
Euro 3 (2000)	50	-	0.5	0.15	-	0.2	0.56	-
Euro 4 (2005)	25	-	0.25	0.08	-	0.1	0.3	-
Euro 5* (2010)	5	5	0.2	0.06	-	0.075	-	-

- Not yet firm

#2 Should there be Different AQGs for Indoors and Outdoors?[1]

The argument I make below is that it is not reasonable to propose different global Air Quality Guidelines (AQGs) for indoor and outdoor air for any single pollutant. Here I focus on households, because, occupational settings are traditionally handled separately from public settings, although some of the same principles discussed below also apply. I make three types of argument:

I. The "laugh test"

The existence of different AQGs, in and out, would lead to logical inconsistencies when applied in real situations, abrogating any utility they might have. Indeed, so glaring are the inconsistencies created that a hypothetical world with different AQGs, indoors and out, does not pass the simple "laugh test." Taking from the tradition of *gedanken* (thought) experiments in physics, consider possible situations in which different AQGs apply indoors and out:

- **AQG laxer indoors,** i.e., the exposure concentration specified indoors is higher than that specified outdoors. This is the case with most suggested guidelines I have seen, including the new Chinese IAQ Standards. It would not pass a "laugh test" because banning use of chimneys, ventilation, or other means of venting indoor pollutants outdoors might sometimes serve to help meet outdoor AQGs without violating indoor ones, but would be difficult to justify to anyone as reasonable or promoting health:
    - *Gedanken* experiment (GE) #1: If pollution levels were such that the tighter outdoor AQG was being exceeded, but not the laxer indoor AQG, would we really recommend that the population close their windows and shut the damper on their fireplaces to keep in the pollution to help meet the outdoor AQG?
    - GE #2: If the same pollution level existed indoors and outdoors and exceeded the tighter outdoor ACG but not the laxer indoor AQG, how could we justify telling people that they were safer indoors doing the same amount breathing of the same pollution that would be unhealthy on the other side of the wall?

- **AQG tighter indoors**. To propose tighter indoor AQGs might seem to be justified because most pollutants for which exposure-response functions were determined with outdoor epi have penetration rates considerably less than 1.0 in most housing. Thus, the health change measured for a 20 ppb outdoor change might actually have been achieved by only a 15 ppb change indoors where people do most of their breathing (we can not separately measure "outdoor and indoor health effects"). It would not seem practical, however, because the varying nature of penetration rates and time activity patterns is not compatible with the need for

[1] Comments by Charles Weschler gratefully acknowledged.

widely applicable, if not universal, AQGs. It would also not pass other laugh tests:

- GE #3: If the tighter indoor AQG as well as the laxer outdoor AQG were both just met, opening the window would be bad if one were indoors, but walking out the door would be ok. On the other hand, opening the same window from the outside would be ok!
- GE #4: If the same pollution level existed indoors and out that exceeded the tighter indoor AQG but not the laxer outdoor AQG, would we be comfortable trying to explain to people that it was unsafe to go indoors to breathe the same pollution that was unhealthy outside?

I have not worked through the *gedanken* experiments for all potential combinations of indoor and outdoor conditions, but I am fairly certain that every single one will reveal logical inconsistencies and that the only reasonable approach is the same AQGs for both locations for public exposures.

One justification for different AQGs indoors and outdoors might be if people are always different indoors and outdoors. The only relevant way this might be true that I can think of is breathing rate. For pollutants in which the rate of breathing is important, ozone perhaps, it might be argued different AQGs are appropriate. See the next section, however, for a counterargument.

II. Not possible or wise to attempt to prejudge behavior of the global population

The second class of argument relates to the meaning of a health-based AQG for public protection:

- It is the intent of the AQGs to provide guidance as to what "safe" living conditions are for the population, no matter where or how fast they are breathing; how they travel about, how they open or close windows, and no matter what the particular indoor/outdoor pollutant relationships are at each time of year in each community.
- People should know that the AQG applies to all situations and if they want to live in a quite different house than the local norm or take exercise wherever is convenient, they will be protected too.

The above arguments conclude that there is little justification for different AQGs indoors and outdoors for the same pollutants, in spite of the well-known phenomenon that outdoor concentrations, on which most epi results are based are not measuring actual exposure, which mostly comes from being indoors.

III. Potential exceptions: particles, VOCs, ozone, and carbon dioxide

Some might argue, however, that there is justification for different AQGs indoors and out for some special pollutants, namely for:

- **Particles**: Although we all know better, we all still use the term particles in most of our work as if they were all the same. Maybe there really is an important difference between the average indoor particle and the average outdoor one, however, thereby potentially justifying different AQGs. In reality, however, this is not a differentiation with regard to where the pollutant is breathed, but in what the pollutant is. If we believe there is something about some indoor particles that makes them less or more unhealthy than typical outdoor particles, we should establish them as a separate pollutant and set guidelines accordingly. Using location is just hiding our inability or unwillingness to address the particle differentiation issue head on.
- **VOCs and similar pollutants found mainly indoors**: There may be important indoor pollutants that require AQGs and not outdoor AQGs simply because they are more common or occur at much higher levels than the same pollutants outdoors. In reality, however, it is just because it is unnecessary that we would not set an outdoor AQG, not that we would set a different one if the pollutant was present outdoors in sufficient amounts. One could think of many other "indoor" pollutants that might fit this category, many also found in occupational settings and the subject of occupational protection guidelines/standards.
- **Ozone**: If it is verified that a significant part of the effect of ozone on health is due to exposure to the secondary pollutants created from it indoors, there may have to be a rethinking of how best to set AQGs overall for this pollutant. For example, setting a AQG indoors at the outdoor value might allow much too high secondary production if there were indoor sources of ozone. Again, however, it may that we will need to focus directly on the pollutants causing the damage.
- **CO_2**: This non-toxic pollutant is commonly used in indoor “AQGs” for commercial and other buildings, but mainly because it is thought to be a good indicator of the more important sorts of human biogenic pollution that are harder to define and measure. Taking a very broad view, however, society is working toward outdoor CO_2 “AQGs” through the efforts to control CO_2 as a greenhouse gas. In this respect, a 1000 ppm limit, as is common in buildings, would be too lax globally (lead to unacceptable health and other damage from climate change) in most people’s estimation.

For the current global AQG-setting activity, perhaps the most relevant issue here is particles. To summarize the argument:

- Much of our profession’s discomfort with having the same particle AQG for all public places, indoors and out, is in reality a discomfort with our, what might be called, **“consensual pretense of undifferentiated PM.”** If so, we should work to specify what makes typical indoor and outdoor PM different pollutants, however, and not hide our discomfort by creating different AQGs based on where people happen to be breathing.

Thus, even when examining these apparent exceptions, there would still be no justification for different AQGs indoors and out for pollutants that are truly the same indoors and out (and for people who are the same indoors and out).

IV. Conclusion: Where the breathing is done should not affect how the pollution is judged.

I would hope that our new Global AQG document might, in addition to its other tasks:

- Derive traditional AQGs for major pollutants that apply to all public settings, indoors and out.

#3 Arguments for Expanding AQGs beyond Exposure Concentration Metrics: The Example of Biomass Smoke

Wood/biomass smoke particles are one of the main contenders for being different enough from the "average" outdoor particle to warrant a different AQG. Although few in number, available outdoor epi studies of woodsmoke do seem to show a shallower exposure-response slope for some health effects. On the other hand, once mixed in the general outdoor air, it is not possible to distinguish the woodsmoke percentage by current or near-future standard regulatory monitoring methods. Indoors, woodsmoke exposures clearly have large health effects in dozens of studies worldwide, but no study has relied on long-term measurements of concentration to determine the risks.

If, as occurred in the previous WHO Global AQG committee, it is decided that indoor PM from biomass combustion, as is common in poor households of developing countries, is truly too different to enable application of outdoor PM epi for establishing an AQG, then we are in trouble, because there is no “indoor” epi using exposure concentrations. What is to be done, therefore, to establish AQGs in these circumstances?

Nearly all indoor epi studies available of biomass smoke, of which there are dozens, are based on more indirect indicators of exposure than even the outdoor exposure concentrations used in outdoor epi. Mainly, of course, this is because it is so easy and cheap for one outdoor measurement location to give an idea of exposure for large populations, while household interiors have to be measured one at a time at great cost per datum. The difference in cost must be several orders of magnitude per data point. Indoor studies thus need to rely on cheaper and more blunt measures of exposure, such as stove or fuel type.

This raises the question, however, whether it would be possible to state AQGs in terms of the same indirect measures that are supported by good epi results instead of exposure concentrations, which are not yet supported. This needs to be considered now because it will be some time, if ever, that there is significant indoor epi using exposure concentrations and in the meantime significant health effects are clearly occurring in large populations.

Consider further the follow options and issues

- A perfectly valid indoor household AQG might be what has been proposed by WHO as development indicator #29 for the Millennium Development Goals, i.e., "over time solid fuels should be phased out as household fuels." I think it can be shown by use of current epi and available measurements that use of solid fuels at the household level with feasible technologies is not compatible with protecting health (both from indoor and outdoor pollution) and any used should be discouraged, e.g., by a properly worded AQG.
- If desired, these non-traditional AQGs could also be stated in highly quantitative ways, for example, "no more than 20% of households should rely on solid fuels for more than 20% of their needs," or any number of such expressions. Of course it allows some household to be above the desired level of risk, but so, in reality, do any of the AQGs using exposure concentrations, which are population-level measures as well, although sounding absolute.
- Of course, this "tight" AQG is not likely to be met soon in much of the world and thus some sort of interim and currently more feasible and more "lax" AQG might be discussed as well, e.g., "all household devices using solid fuels should be vented to the outdoors."

I realize that the idea of framing an AQG in any way except an exposure concentration will be disturbing to many, but consider that even the exposure concentrations we use, although presented in a seemingly highly quantitative manner, are actually surrogates for what we recognize would be even better measures if we could afford to make them or completely understood them. Two of the most important ways ambient measurements are surrogates are that they do not completely indicate personal exposures and that the measure of one pollutant is often highly correlated with that of others, making it difficult to single out which is the primary cause of ill-health or whether it is some function of the mixture. Nevertheless, we are willing to propose and live with ambient exposure concentrations as the metric in AQGs and standards.

I also recognize that some observers may demur because, however phrased, such non-exposure-concentration indicators would not have the technical simplicity and apparent neutrality of current AQGs. Wait until the data are better so that we can use the same metrics for indoor biomass smoke, might be the response. I would ask in return, however, whether we feel comfortable telling policy makers concerned with the health of groups exposed to solid fuel smoke indoors to wait until that day, probably at least several decades away, when we feel comfortable enough to issue standard AQGs before offering anything at all to guide their actions?

To conclude, I would hope that our new Global AQG document might, in addition to its other tasks:

- Derive non-traditional AQGs for situations in which the available epi is persuasive, but the exposure metrics happen to be different from those commonly found in outdoor epidemiology, i.e., exposure concentrations.

#4 Institutionalizing the Global AQG System: Lessons from ICRP

Although WHO should be praised for finding the resources for the roughly once every decade effort to update Global AQGs, the growing complexity, breadth, and importance of the issues would seem to call for more consistently performed reviews, more focused reports on individual critical subjects in the interim, and a full-time secretariat to manage the activity. There are a number of justifications for such a conclusion, but consider four:

- Cost of under-controlling: As it is estimated that close to three million people currently die prematurely each year from the effects of indoor, outdoor, and occupational air pollution exposures, the potential for public health improvement is immense;
- Cost of over-controlling: As control costs are large and affect significant portions of the economy (energy, transport, etc.), there is great need for high-quality and timely information to counter the inevitably powerful pressures against control.
- Rapidly changes in scientific knowledge: As the extent of knowledge about the extent, character, interactions, toxicology, and epidemiology of exposures is growing at a pace that demands more detailed reviews of important topics so that regularly conducted overall reviews are informed to the best extent possible.
- Demands of development: As countries develop there are shifts in both the character and impact of exposures, but also in public expectations and ability to pay for control.

Although much valuable information can be gleaned from assessments done by USEPA, NRC/NAS, HEI, CARB, EU/EC, UKMRC, and other first-world institutions with air pollution mandates, these are not focused on the situations relevant to middle-income and poor countries. These countries share some of the same problems and concerns, but have many others not addressed at all or only peripherally in the highly competent assessments done, mostly, by North American and European organizations. There is thus a real need for timely reports on important issues tailored to parts of the world not able to mount large-scale sustained internal evaluation efforts needed to make scientifically credible recommendations.

The ICRP: a possible model

The International Commission for Radiological Protection (ICRP) is a venerable organization with roots back into the 1920s, but restructured to its modern form in 1950. Its mission statement (http://www.icrp.org/):

> *The International Commission on Radiological Protection, ICRP, is an independent Registered Charity, established to advance for the public benefit the science of radiological protection, in particular by providing recommendations and guidance on all aspects of protection against ionising radiation.*

ICRP regularly convenes groups of scientific experts to review the evidence on health effects, measurement methods, exposure and dose metrics, risk assessment methods, and other issues related to radiation and issues reports containing guidelines for use by policy makers and regulatory bodies. It is the primary source of such information internationally and its recommendations are adopted by an overwhelming majority of countries.

It is instructive to examine the extent of ICRP reports in support of policy making. Many of the issues they address have exact parallels for air pollution. Here I will focus mainly on small particle pollution (PM), but much would relate to other pollutants as well. A quick look just at reports since 2000, for example, reveals the list below that would be worthy of detailed PM reports on the same subjects:
http://www.elsevier.com/wps/find/bookseriesdescription.cws_home/BS_ICRP/description

- Links between public and occupational exposures and health effects (a subject scandalously absent in the PM literature)
- Special considerations for children
- Special considerations for pre-natal exposures
- Special considerations for pregnant women
- How do deal with terrorist attacks or other disasters leading to high exposures
- Impacts on non-human species
- How to determine and interpret deposition patterns in the respiratory system
- Risk estimates when dealing with multi-factorial diseases
- Differences between short- and long-term exposures
- Genetic susceptibility

The ICRP's many reports on measurement methods and exposure/dose metrics mirror areas of substantial concern with PM as well.

Possible recommendation

Although aimed at probably the most important air pollutant for health, an International Commission on Particle Protection (ICPP) might be seen as too narrow in some quarters to handle all non-radiological airborne contaminants of concern. Thus, perhaps promoting an International Commission on Air Pollution Protection (ICAPP) with a strong PM sub-division, would be a more appropriate and flexible approach.

There has also been a call for a Particle Effects Research Foundation (PERF), in parallel to the Radiation Effects Research Foundation (RERF) in Japan. RERF has provided much of the important research on the health impacts of ionizing radiation and, like the ICRP, enjoys an excellent reputation as a well-run and scientifically sound organization producing independent results. Such an effort is needed to fill in the important gaps in knowledge about particle health effects and other issues in parts of the world not well served by current research patterns. It is warranted for the same reasons stated above plus the strong links of PM with other impacts, particularly climate change and acid precipitation. Although the ICAPP and PERF might potentially be part of the same institutional framework, there are advantages in keeping the research and policy agendas separate.

When resources are available, of course, WHO has been able to conduct reports on air pollution issues as it is now doing with the global AQGs. Unfortunately, however, this has been *ad hoc* and reliant on the sometimes heroic efforts of a small handful of dedicated individuals within the organization operating with little institutional support.

What is needed is to upgrade, expand, regularize, and, in general, institutionalize these efforts to directly address the three million premature deaths in the world from air pollution by incorporating strong consistent scientific advisory boards and full-time professional management into an ICAPP or equivalent that could fill the gaps in needed information with a continuing series of high-quality reports and other activities. It may well be possible to place such an activity within WHO, but there are probably good arguments for structuring it either as a completely independent body, such as ICRP, or perhaps as a semi-independent separately funded activity for which WHO is the executing agency, such as the International Programme on Chemical Safety (IPCS).
