The revised US national standard for sulphur dioxide

Louise Wickham, Emission Impossible Ltd (NZ)

Abstract

As readers may be aware, in June 2010 the US EPA promulgated a revised short-term (1-hour) primary national air quality standard for sulphur dioxide (Federal Register 2010). This article reviews the reasons behind the final standard. The rule setting the standard is well written and is quoted verbatim in places here.

Summary

The US EPA has revised the primary sulphur dioxide national air quality standard (NAAQS) to provide requisite protection of public health with an adequate margin of safety. Specifically, EPA has established a new 1-hour sulphur dioxide standard at a level of 75 ppb (= 200 µg m^{-3} at 20°C), based on the 3-year average of the annual 99th percentile of 1-hour daily maximum concentrations. The EPA has also revoked both the existing 24-hour and annual primary sulphur dioxide standards. The new standard was effective from August 23, 2010.

Background

In setting standards that are "requisite" to protect public health and welfare, EPA's task is to establish standards that are neither more nor less stringent than necessary for these purposes. Importantly, in doing so EPA may *not* consider the costs of implementing the standards (Decision 2001).

It is instructional to note that full attainment of the new NAAQS by 2020 will achieve only $2.2 million in benefits from reduced sulphur dioxide exposure. For an estimated $1,500 million in costs, this yields a rather unattractive benefit to cost ratio. Importantly, however, the rule will have staggering co-benefits of **\$15 – 37 billion** due to reduced $PM_{2.5}$ exposure ($PM_{2.5}$ is formed as a secondary pollutant from sulphur dioxide).

Additional actions to support revised standard

The US EPA has also promulgated the Clean Air Interstate Rule (CAIR) to require additional sulphur dioxide emission reductions needed in the eastern half of the United States. This will address emissions which contribute significantly to nonattainment with, or interfere with maintenance of, the PM NAAQS by downwind States in the CAIR region.

Rationale for decision on the primary standard

The rule notes that "in reaching this decision, EPA has drawn upon an integrative synthesis of the entire body of evidence on human health effects associated with the presence of sulphur dioxide in the ambient air, and upon the results of the quantitative exposure and risk assessments reflecting this evidence." Specifically, in considering this body of evidence, EPA has focussed primarily on those health endpoints for which the Integrated Scientific Assessment for Oxides of Sulphur - Health Criteria (ISA) established a causal relationship (EPA 2008).

This is important - a "causal relationship" is the strongest finding the ISA can make *i.e.*:

> *... [E]vidence [that] is sufficient to conclude that there is a causal relationship between relevant pollutant exposures and the health outcome. That is, a positive association has been observed between the pollutant and the outcome in studies in which chance, bias, and confounding could be ruled out with reasonable confidence. Evidence includes, for example, controlled human exposure studies; or observational studies that cannot be explained by plausible alternatives or are supported by other lines of evidence (e.g. animal studies or mechanism of action information). Evidence includes replicated and consistent high-quality studies by multiple investigators.*

The ISA found that there was sufficient evidence to infer a "causal relationship" between respiratory morbidity and short-term (5-minutes to 24-hours) exposure to sulphur dioxide. This conclusion was based on "the consistency, coherence, and plausibility of findings observed in controlled human exposure studies of 5-10 minutes, epidemiologic studies mostly using 1-hour daily maximum and 24-hour average sulphur dioxide concentrations, and animal toxicological studies using exposures of minutes to hours." Specifically:

> *…exposure to sulphur dioxide concentrations as low as 200 – 300 ppb [530 – 800 µg m^{-3}] for 5-10 minutes at 20°C results in approximately 5-30% of exercising asthmatics experiencing moderate or greater decrements in lung function* (Federal Register 2010).

EPA approach to reviewing the standard

The following may be of interest to regulators in both Australia and New Zealand. The EPA used the following questions to frame the consideration of scientific evidence and exposure/risk-based information.

- To what extent does evidence that has become available since the last review reinforce or call into question evidence for sulphur dioxide associated effects that were identified in the last review?
- To what extent has evidence for different health effects and/or susceptible populations become available since the last review?
- To what extent have uncertainties identified in the last review been reduced and/or have new uncertainties emerged?
- To what extent does evidence and exposure/risk-based information that has become available since the last review reinforce or call into question any of the basic elements (indicator, averaging time, form, and level) of the current standard?
- Is there evidence that associations, especially causal or likely causal associations, extend to ambient sulphur dioxide concentrations as low as, or lower than, the

concentrations that have previously been associated with health effects? If so, what are the important uncertainties associated with that evidence?

- Are exposures above benchmark levels and/or health risks estimated to occur in areas that meet the current standard? If so, are the estimated exposures and health risks important from a public health perspective? What are the important uncertainties associated with the estimated risks?
- Does the evidence provide support for considering a different indicator for gaseous oxides of sulphur (SO_x)?
- Does the evidence provide support for considering different, or additional averaging times?
- What ranges of levels and forms of alternative standards are supported by the evidence, and what are the associated uncertainties and limitations?
- To what extent do specific averaging times, levels, and forms of alternative standards reduce the estimated exposures above benchmark levels and risks attributable to exposure to ambient sulphur dioxide, and what are the uncertainties associated with the estimated exposure and risk reductions?

Form of the standard

Detailed consideration was given to the form of the standard. This included both the time average and whether or not a percentile-based or exceedance-based form is more appropriate. EPA concluded that a concentration-based form, averaged over three years, is appropriate because it gives proportionally greater weight to years when 1-hour daily maximum sulphur dioxide concentrations are well above the level of the standard, than it gives to years when 1-hour daily maximum sulphur dioxide concentrations are just above the level of the standard. In contrast, an expected exceedance-based form gives the same weight to years when 1-hour daily maximum sulphur dioxide concentrations are just above the level of the standard as it gives to years when 1-hour daily maximum sulphur dioxide concentrations are well above the level of the standard.

Thus, a concentration-based form, averaged over three years, better reflects the continuum of health risks posed by increasing sulphur dioxide concentrations (i.e. the percentage of asthmatics affected and the severity of the response increase with increasing sulphur dioxide concentrations). Further, a concentration-based standard increases the stability of the standard (as compared with a no-exceedance based form).

In addition to this, EPA notes that in most locations analysed, a 99th percentile form would correspond to the 4th highest daily maximum concentration in a year, and that the 99th percentile, combined with the standard level selected, will substantially limit 5-minute peaks of sulphur dioxide above the 200 ppb and higher benchmark levels.

Separating effects of sulphur dioxide from other pollutants

To some extent the review was simplified because of the primary focus on the causal relationship between respiratory morbidity and short-term (5-minutes to 24-hours) exposure to sulphur dioxide (only). However, the rule has this to say on the matter of the separating the effects of co-pollutants:

> *...we agree that the interpretation of sulphur dioxide epidemiologic studies is complicated by the fact that sulphur dioxide is but one component of a complex mixture of pollutants present in the ambient air. However, the ISA concluded that when U.S. and international epidemiologic literature is evaluated as a whole, sulphur dioxide effect estimates generally remained positive and relatively unchanged in multi-pollutant models with gaseous or particulate co-pollutants. Thus, although recognising the uncertainties associated with separating the effects of sulphur dioxide from those of co-occurring pollutants, the ISA concluded that the limited available evidence from studies employing multi-pollutant models indicates that the effect of sulphur dioxide on respiratory health outcomes appears to be generally robust and independent of the effects of gaseous co-pollutants, including nitrogen dioxide and ozone, as well as particulate co-pollutants, particularly $PM_{2.5}$.*

In addition, the ISA emphasised that controlled human exposure studies provide support for the plausibility of the associations reported in epidemiologic studies. The ISA noted that the results of controlled human exposure and epidemiologic studies form a plausible and coherent data set that supports a causal relationship between short-term (5-minutes to 24-hours) sulphur dioxide exposures and adverse respiratory effects, and that the epidemiologic evidence (buttressed by the clinical evidence) indicates that the effects seen in the epidemiologic studies are attributable to exposure to sulphur dioxide.

Not surprisingly, this view was widely contested and detailed supporting evidence is provided in the final rule.

Timeframes

The rule mandates the following timelines from promulgation (June 2010):

- June 2011 - States to nominate initial area designations ("attainment", "non-attainment", unclassified)
- June 2012 - EPA to promulgate area designations
- 1 January 2013 - Monitoring sited and operational
- June 2013 and August 2017 - State implementation plans demonstrating attainment and maintenance submitted to EPA
- February 2014 - State implementation plans for nonattainment areas submitted to EPA (and must show attainment no later than August 2017)
- June 2014 - EPA approval (or disapproval) of state implementation plans for attainment and unclassifiable areas
- February 2015 - EPA approval (or disapproval) of state implementation plans for nonattainment areas
- June 2016 - EPA issue federal improvement plans for disapproved state implementation plans

- February 2017 - EPA issue federal improvement plan for nonattainment areas with disapproved state implementation plans
- August 2017 – **all areas** achieve attainment, implementation, maintenance and enforcement of the new sulphur dioxide NAAQS.

Monitoring

Minimum monitoring requirements are mandated through the introduction of a population weighted emissions index (PWEI). This is calculated as follows:

PWEI = population x emissions / 1 million

where;

Population = each Core Based Statistical Area (CBSA); and

Emissions = tonnes per year of sulphur dioxide from the national emissions inventory (in each CBSA).

Minimum monitoring requirements are therefore:

PWEI ≥ 1,000,000	three monitors
100,000 ≥ PWEI ≥ 1,000,000	two monitors
5,000 ≥ PWEI ≥ 100,000	one monitor

Interestingly, for New Zealand, this would equate to two monitors for the entire country.

Implementation – a fundamental shift

Importantly, EPA has fundamentally changed their approach to monitoring and implementation of the sulphur dioxide standard. Specifically, EPA intends to adopt a "hybrid analytic" approach that combines the use of monitoring and modelling to assess compliance. The intent is to better address:

- The unique source-specific impacts of sulphur dioxide emissions
- The special challenges sulphur dioxide emissions present in terms of monitoring short-term sulphur dioxide levels for comparison with the NAAQS in many situations;
- The superior utility that modelling offers for assessing sulphur dioxide concentrations; and
- The most appropriate method for ensuring that areas attain and maintain the new 1-hour sulphur dioxide NAAQS in a manner that is as expeditious as practicable.

This is a big change. In simple terms it means that, instead of monitoring, **states may use dispersion modelling as their primary means for identifying violations and demonstrating compliance with the new standard**. EPA notes:

> *Historically, we have favoured dispersion modelling to support sulphur dioxide NAAQS compliance determinations for areas with sources that have the potential to cause a sulphur dioxide NAAQs violation, and we have explained that for an area to be designated as "attainment", dispersion modelling regarding such sources needs to show the absence of violations even if monitoring does not show a violation.*

The EPA intends to issue new, additional, guidance on dispersion modelling to support implementation of the new standard. The initial focus is to be on sources emitting more than 100 tonnes of sulphur dioxide per year. EPA estimates there are approximately 2000 such sources that are collectively responsible for around 99% of all sulphur dioxide emissions from point sources in the US. By comparison New Zealand has around 30 sources and Australia has around 115 sources emitting greater than 100 tonnes of sulphur dioxide per year (New Zealand 2007; Australia NPI 2009/10).

State implementation monitoring plans

New Zealand regulators may be interested in the mandatory requirements for state implementation plans, which include:

- Enforceable emission limits
- Timetables for compliance
- Appropriate testing/reporting to assure compliance and demonstrate attainment through air quality modelling for all sources contributing to monitored and modelled violations (or those that have the potential to cause or contribute to a violation of the NAAQS).

As an aside, New Zealand has recently removed mandatory requirements for linear annual improvement (“straight line path”) in emissions reduction for areas not achieving the national standard for PM_{10} (Resource Management 2011). It is with interest to see then that state implementation plans for nonattainment areas must provide for “reasonable further progress”, which is further defined as:

> *Such annual incremental reductions in emissions of the relevant air pollution as are required by part D* [of the Clean Air Act]*, or may reasonably be required by the Administrator for the purpose of ensuring attainment of the applicable NAAQS by the applicable attainment date* (Federal Register 2010).

In the event that states fail to submit a state implementation plan, or do not meet scheduled timeframes, EPA may disapprove plans and/or establish federal implementation plans instead. Approval centres on whether or not a plan can show attainment, implementation, maintenance and enforcement of the new NAAQS as expeditiously as practicable (i.e. by August 2017). Of note, “maintenance” plans must contain the following elements:

- An attainment emissions inventory
- A control strategy
- A maintenance demonstration, using EPA approved air quality model as appropriate
- A contingency plan
- A plan for verification of continued attainment of the standard.

Supporting industrial emissions programmes

The Clean Air Act (the Act) restricts new industrial emissions for sources that are large through the prevention of significant deterioration (PSD) programme and the new source review (NSR) programme. There are significant overlaps between these programmes and regulatory requirements in existence in New Zealand (and parts of Australia):

PSD requires:

- Offsetting new emissions with creditable emissions reductions
- An alternatives and siting analysis
- Public comment on the permit.

NSR requires:

- "Significant emissions rate" defined as one that results in a modelled ambient impact of less than 4% of the short-term NAAQS

In New Zealand the national environmental standards for air quality in New Zealand require offsets for any new industry in a polluted airshed that will have an ambient impact at 5% of the PM_{10} standard. The Resource Management Act 1991 further requires public consultation (and input) on new permits as well as alternatives analysis.

However, the US also has some more stringent requirements than those mandated in either Australia or New Zealand. For example:

NSR requires:

- Requirement for installation of lowest achievable emissions rate control technology; and
- A certification that all major sources owned and operated in the State by the same owner are in compliance with all applicable requirements under the Act.

Conclusion

Judging by the detailed discussion and justification of every aspect of the proposal evident in the final rule, the new standard appears to have been hotly contested, at length, in the United States. The new short-term (1-hour) standard of 75 ppb is more stringent than those it replaces (140 ppb as a 24-hour average, 30 ppb as an annual average). However, the use of a 99th percentile still permits 88 hours that can exceed the new standard, albeit averaged over three years.

What is interesting is the detailed implementation package proposed to support the new standards. This includes federal rules to clean up large sources that impact on other states downwind as well as the proposed intent of utilising dispersion modelling, in addition to monitoring, to investigate and demonstrate compliance. To some extent, this new hybrid approach reflects the highly regulated environment for atmospheric dispersion modelling, and indeed air quality management, in the United States. Australia and New Zealand enjoy significant latitude in their application of dispersion models and air quality management processes. The success, or otherwise, of the US EPAs new hybrid approach will be watched keenly by regulators in Australia and New Zealand.

References

Australian National Pollutant Inventory, 2009/10, *Sulphur Dioxide*, available at www.npi.govt.au.

Decision 2001 in *Whitman v. American Trucking Associations,* 531 U.S. 457, 471, 475-76.

EPA 2008, *Integrated Science Assessment (ISA) for Sulphur Oxides – Health Criteria (Final Report)*. EPA/600/R-08/047F. Available at: http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=198843.

Federal Register 2010, June 22, *Primary National Ambient Air Quality Standard for Sulphur Dioxide: Final Rule*. Part II, Environmental Protection Agency, 40 CFR Parts 50, 53 and 58,. Available at http://www.epa.gov/ttn/naaqs/standards/so2/s_so2_cr_fr.html.

New Zealand 2011, *New Zealand Sulphur Dioxide Industrial Emission Inventory – 2007*, unpublished, Ministry for the Environment.

Resource Management 2011, *National Environmental Standards for Air Quality Amendment Regulations 2011* Available at www.legislation.govt.nz

Author

Louise Wickham, Emission Impossible Ltd

Auckland, New Zealand

louise@emissionimpossible.co.nz